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BATS OF THE MEXICAN STATE OF GUERRERO

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Recent developments in the study of rabies in bats have generated considerable interest in the distribution of bats in Mexico. Consequently, it seems desirable to bring together data we have accumulated through field studies in Guerrero in 1952–54 and 1956 and by a survey of the published literature. In all, we have records for Guerrero of 29 species of bats representing 7 families as follows: Emballonuridae, 2; Noctilionidae, 1; Phyllostomidae, 18; Desmodontidae, 1; Natalidae, 1; Vespertilionidae, 4; Molossidae, 2. The preponderance of Neotropical species is clearly indicated by the tabulation.

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ACCOUNTS OF SPECIES

Saccopteryx bilineata (Temminck).—The present known distribution of this bat in southern Mexico indicates that it is a tropical, lowland-dwelling form. Davis examined 3 specimens from Acapulco and 18 from Papayo in the U. S. National Museum. Sanborn (1937) also reported on some of these same specimens.

Balantiopteryx plicata plicata Peters.—The size of the forearm, 39 to 43 mm., average 41; the absence of a white line on the edge of the wing membrane; and the larger skull (condylobasal length 12.2 to 13.2 mm., average 12.6; zygomatic breadth 8.7 to 9.1 mm., average 9.0) distinguish *B. plicata* from *B. io* which occurs in Mexico mainly in the eastern coastal states. Although no specimens of *B. p. pallida* Burt were available for comparison, the subspecies *B. p. plicata* apparently differs from *pallida* in its larger size and darker, more brownish color (Burt, 1948). The cranial measurements of our 21 specimens of *plicata* from central Guerrero compare well with those recorded by Sanborn (1937) for this bat from a larger area of southern Mexico. Adults weighed from 5.0 gr. to 7.3 gr.

The sac-winged bat is one of the smaller and more common bats in the area studied. Specimens were collected in several diverse situations. Many were taken in caves near Acahuizotla and Colotlipa; seven were collected in a rock culvert underneath the highway southwest of Tierra Colorada; two were found under boulders on a hillside; one was shot while in flight. In one instance near Colotlipa, large numbers of both males and females were inhabiting the same cave in July with *Glossophaga* and *Natalus*. At Acahuizotla it was found in a cave with *Macrotus, Glossophaga, Desmodus,* and *Micronycteris*.

These are the first bats to appear in the evening, often before sunset. At Mexcala they appeared during twilight and flew in small circles low over the camp area and apparently foraged on insects that were drawn to our lanterns. Our efforts to shoot them or catch them in a bat net failed, and they disappeared shortly after total darkness. South of Tierra Colorada, on the Río Xolapa, large numbers of these bats were seen wheeling back and forth across the stream bottoms 20 to 30 feet above the ground. They first appeared in nearly full daylight and most were gone by dark. They seem to be restricted to altitudes below 3,000 feet. A good account of their habits is given by Davis (1944).

Specimens examined, 24, as follows: Acahuizotla, 2,800 ft., 1; Acapulco, 2 (B. S. Coll.); 30 km. N Acapulco, 1; Colotlipa, 2,700 ft., 1; 1 mi. SW Colotlipa, 2,700 ft., 6; 4 mi. N Colotlipa, 3000, ft., 1; Cañon del Zopilote, 16 km. from Río Balsas, 2,100 ft., 1; 14 km. NE Mexcala, 2,100 ft., 1; Rincón, 2,600 ft., 1; 14 km. SW Tierra Colorada, 600 ft., 7; 1 mi. SW Tierra Colorada, 900 ft., 2. Additional records: 5 mi. NW Acapulco, 26, and 12 mi. S Mexcala, 1 (Torre, 1955).

Noctilio leporinus mexicanus Goldman.—This subspecies was described by E. A. Goldman on the basis of 9 specimens collected by Nelson and Goldman in 1903 at Papayo, Guerrero (Goldman, 1915). An effort should be made to supplement the meager information available concerning the occurrence and distribution of this bat in Mexico, for apparently no additional examples of it have been taken.

Chilonycteris rubiginosa mexicana Miller.—Our three examples were taken in a large humid cave overlooking the Río Balsas, a cave which these bats shared with *Macrotus* and *Desmodus*. All are in the brown color phase. The adult male weighed 15.0 gr.; the two adult females, 11.5 gr. and 12.5 gr.

In Guerrero, as in other parts of Mexico, the greater mustache bat seems to prefer arid lowlands. It is to be expected that its distribution in Guerrero will eventually be shown to be more widespread than present records indicate. For a discussion of the use of the name *C. rubiginosa* see Koopman (1955) and Torre (1955).

Specimens examined, 3, all from 3 mi. W Mexcala, 2,000 ft. Additional records: 5 mi. NW Acapulco, 8 (Torre, 1955); Yerbabuena, 12 km. NE Teloloapan, 8 (Martinez and Villa, 1941); Ometepec, 3 (Rehm, 1904*b*).

Chilonycteris psilotis Dobson.—The only record of this species from Guerrero is that of 3 specimens from 5 mi. NW Acapulco reported by Torre (1955), who is of the opinion that the small Mexican *Chilonycteris* is referable to

C. psilotis rather than to the Brazilian *C. personata.*

Pteronotus davyi fulvus (Thomas).—The extension of the naked volar membrane up over the posterior half of the body, the small size, and the inflated rostrum immediately denote this bat as *P. davyi.* Because the first upper premolar is crowded between the canine and the second premolar arranged so that its greatest length is almost transverse, our one specimen is assignable to the subspecies *P. d. fulvus.* External and cranial measurements agree well with those given by Rehn (1904*b*:225) for *fulvus.*

Our single naked-backed bat, shot in flight about 9:00 P.M. on the bank of the Río Xolapa, is a female in the brown color phase that weighed 7.5 gr. It was feeding on insects which were attracted to the light of our gasoline lanterns and was the only bat present at the time. This particular bat was active much later in the evening than has previously been reported (Dalquist, 1953*a*). Davis and Russell (1952) collected *P. davyi* over a low marshy area, and Dalquest (*loc. cit.*) took most of his naked-backed bats near tropical lowland rivers and streams. Since our specimen was also taken beside a stream, it seems evident that these bats prefer to forage near water.

Specimens examined, 5, as follows: 8 mi. SW Tierra Colorada, 600 ft., 1; Caves of Cacahuamilpa, 4. Additional records: Acapulco, 2 (Rehn, 1904*a*); 5 mi. NW Acapulco, 11 (Torre, 1955); Ynez, 1 (M.C.Z.).

Moormoops megalophylla megalophylla Peters.—Davis examined one specimen (B.S.C.) of this subspecies from Acapulco. Seemingly the only account of its presence in Guerrero is that of 27 specimens from 5 mi. NW Acapulco (Torre, 1955). Little seems to be known regarding the habits and distribution of this bat in southern and southwestern Mexico. Additional collections of both *M. m. megalophylla* and *M. m. senicula* from their entire range in Mexico should be made in order to clarify the relationships of these two forms.

Micronycterus megalotis mexicana Miller.—The little big-eared bat is one of the less common bats of Guerrero. All of our specimens were taken during the day in caves, but it is thought that they may also use highway culverts and various other secluded places for daytime retreats. Four of them, two adult females, one adult male, and a half-grown young (4.8 gm.), were taken July 1 in one of a series of small limestone caves near Acahuizotla. These bats were hanging near the entrance to a larger cave where there was a limited amount of light, and no other bats were present in the cave at that time.

Near Almolonga two other specimens, an adult male and an adult female, were found hanging together in a large crevice on a hillside overlooking a cleared valley. Our limited observations indicate that this species prefers retreats in which there is some illumination. Four of our adult specimens are in the brown phase; one is distinctly reddish. Adults weighed from 7.0 gr. to 7.8 gr. Little is known about the habits of these bats in Guerrero, but a partial account of their natural history in San Luis Potosí is given by Dalquest (1953*a*). Our specimens constitute the first record of this bat in Guerrero.

Specimens examined, 6 as follows: Acahuizotla, 2,800 ft., 4; 2.5 mi. S Almo-

longa, 5,600 ft., 2.

Macrotus mexicanus mexicanus Saussure.—Our specimens are from the second locality record for Guerrero and comprise a southward range extension of the species in the state. These bats seemingly are restricted to arid lowlands such as those found in the Balsas Basin. Our three examples were collected in a large humid cave whose entrance overlooks the Río Balsas. They were inhabiting the main chamber of the cave along with *Desmodus* and *Chilonycteris*. The number of bats using that cave must be considerable because the local residents are presently mining it for guano. Our specimens, all males weighing from 12.5 gr. to 15.0 gr., are in the brown color phase.

Specimens examined, 3, are from 3 mi. W Mexcala, 2,000 ft. Additional record: 8 km. E Teloloapan (Martinez and Villa, 1940).

Glossophaga soricina leachi (Gray).—This species is apparently one of the more common cave-dwelling bats in the interior lowlands of central Guerrero. All but one of our specimens were collected in caves of varying sizes and depths. The exception, an adult male, was the only one captured of a group of several bats using a highway culvert as a daytime retreat. The caves which these bats inhabited were located on heavily wooded hillsides in the Tropical Deciduous Forest.

These bats are gregarious, often congregating in groups of several hundred individuals. Dalquest (1953*a*) suggests that males roost separately from females, at least in mid-summer, but we found both males and females dispersed throughout the same chamber in a large limestone cave near Colotlipa in late June. In that same cave, an exceedingly hot, humid cavern with a thick layer of guano on the floor, *Balantiopteryx*, *Natalus*, and *Artibeus hirsutus* were also found. The bats were so numerous there that they could be knocked out of the air with a hat, and several members of the collecting party were accidentally hit by flying bats. *Glossophaga* was collected in the same caves with *Desmodus* and *Natalus* at Acahuizotla. The specimen from near Taxco was captured in a "mist" net placed across a cypress bordered stream along which these bats appeared to be foraging.

The color of our specimens, which varies from deep, dark brown through lighter brown, to almost reddish, does not seem to be correlated with either sex or geographic position. Apparently these color variations occur in all populations. Comparison with *G. s. alticola* from Morelos shows that the darkest *G. s. leachi* is distinctly lighter and much browner than any of *alticola*. No apparent difference was noted between external and cranial measurements of our specimens from Guerrero and those measured by Russell (1952) from Morelos and by Dalquest (*op. cit.*, 24) from San Luis Potosí.

Several males taken in late June and early July had testes ranging from 4 to 8 mm. in length. All of the specimens taken during the same period appear to be adults. Weights of 14 males averaged 9.3 gr.; of 9 females, 8.8 gr. A female taken at El Papayo on Dec. 30 contained one embryo 7 mm. in C–R length.

Specimens examined, 32, as follows: Acahuizotla, 2,800 ft., 3; 4 mi. N Colotlipa, 3,000 ft., 21; 14 km. SW Tierra Colorada, 600 ft., 1; 17 km. S Taxco, 4,000

ft., 1; El Papayo, 25 ft., 6. Additional records: 6 km. N Cuetzala del Progreso (Martinez and Villa, 1941); 5 mi. NW Acapulco, 9 (Torre, 1955).

Choeronycteris mexicana Tschudi.—This species has been recorded from Michoacán (Hall and Villa, 1949), Morelos (Davis and Russell, 1952) and Hidalgo and Tlaxcala (Davis, 1944) in a wide variety of habitats, all of which are principally arid and range in altitude from 3,100 to 7,800 feet. Consequently, there is reason to expect that the Mexican long-tongued bat is more common and widespread in Guerrero than our one specimen indicates.

This specimen constitutes a southern range extension for the species and is the first record from Guerrero. It was found alone in a cave on a hillside near Rincón, at an elevation of 2,600 feet. Series of adults of this species from Morelos and Hidalgo exhibit sexual dichromatism—the females are brownish, the males reddish. Our one specimen, labeled a male, has a brownish rather than a reddish pelage, but since it weighed only 12.7 gr. (adults from Morelos and Tlaxcala weighed from 15.5 gr. to 18.1 gr.), it appears to be a young individual that is incorrectly sexed.

Leptonycteris nivalis nivalis (Saussure).—The long-nosed bat apparently occurs in Guerrero only in the Balsas Basin. One specimen was taken 12 miles south of Mexcala (Torre, 1955). Martinez and Villa (1940) collected examples from caves near Yerba Buena and Cuetzala del Progreso, both of which are short distances north of Mexcala and the Río Balsas. These authors and Davis and Russell (1952) found this species sharing caves with *Macrotus* and *Chilonycteris*. Since we collected specimens of both the last two genera in a cave 3 miles west of Mexcala, *L. nivalis* may reasonably be expected to occur there also.

Corollia subrufa (Hahn).—Little information relative to *C. subrufa* is present in the literature, and we have encountered no recent records of its occurrence in southern Mexico. Seemingly our three specimens, two adult males weighing 15.4 gr. and 17.0 gr., and one gravid female taken Dec. 31 and weighing 14 gr., constitute the most recent record from that part of Mexico and are the first reported from Guerrero. Hahn (1907) listed specimens from Colima and Oaxaca to the north and south of Guerrero, so it was anticipated that it occurred also in the intervening area.

Two of our bats were taken at night in an old tomb-like structure in the village of Acahuizotla at an elevation of 2,800 feet; the female was captured in a net in a cocoanut grove at El Papayo, 25 ft. She contained one embryo 9 mm. in C–R length.

Sturnira ludovici Anthony.—This is another rare bat in Mexico. Dalquest (1953*a*) reported five specimens from Xilitla, San Luis Potosí, and Torre (1954) one from Jalisco. This species can be recognized by its nose leaf, comparatively small size, lack of interfemoral membrane, yellowish shoulder patch, and upper and lower molars with a well defined longitudinal groove which is continuous from tooth to tooth with the cusps lateral. It differs from *S. lilium* in having M^2 turned at a slight angle inward from M^1 (symmetrical in *lilium*) and bilobate lower incisors (trilobate in *lilium*).

No specimens of S. *ludovici* were available for comparison, but our one adult female seems to be somewhat smaller than those recorded by Hershkovitz (1949) from Colombia and Dalquest (*op. cit.*) from San Luis Potosí. The measurements given by Goodwin (1946) for one bat from Costa Rica listed as S. *hondurensis* correspond closely to those of our specimen.

Measurements of our female: Total length, 65; length of hind foot, 12; height of ear, 18; length of forearm, 43; mastoidal width, 11.5; length of skull, 22.8; condylobasal length, 20.5; zygomatic breadth, 13.4; interorbital width, 6.0; breadth of brain case, 10.6; width across canines, 5.9.

This bat was taken about 8:00 p.m. in December in a "mist" net set on a brush-covered hillside two miles west of Omiltemi, 7,900 ft. elevation. It struck the net about 5 feet above the ground and struggled violently to free itself. It contained no embryos. S. *ludovici* seemingly prefers a heavily forested habitat at high elevations. This specimen represents the initial record for Guerrero.

Sturnira lilium parvidens Goldman.—We have no records of the occurrence of this species in Guerrero since Nelson and Goldman collected the type specimen at Papayo in 1903. Seemingly this is a species of the lowlands, whereas S. *ludovici* is a highlands form.

Artibeus hirsutus Andersen.—The first revision of the genus *Artibeus* by Andersen (1908) stood uncontested until Hershkovitz (1949) pointed out the inherent fallacies in Andersen's conclusions. Using Hershkovitz's work as a background, Dalquest (1953*b*) presented a synopsis of the Mexican forms of the genus. On the basis of our material from Guerrero, the arrangement proposed by Dalquest for the fruit bats seems to be logical, and the classification that he employs is adopted here. However, it should be emphasized that the fruit bats of Mexico are not at present well known, at least by us. The classification of the genus is presently in a state of flux and "the exact status of some forms must await a revision of the entire genus" (Dalquest, *op. cit.*, p. 62).

The genus *Artibeus* is a fairly large and complex group in Guerrero and is represented there by more species than any of the other genera of bats. To date, five species of fruit bats have been collected in central Guerrero, three of which have not previously been recorded from that state. These five species seem to represent two general groups, one of large size embracing the species *A. lituratus, A. jamaicensis,* and *A. hirsutus;* the other is a group of smaller bats including *A. cinereus* and *A. nanus.* In addition to the general size difference between the two groups, the larger ones also have in common a "mantle," or lighter colored neck and shoulder region. This mantle is absent in *cinereus* and *nanus.* In the discussions which follow, this "groups" arrangement is used in comparing the more closely related forms.

A. hirsutus, described originally from La Salada, Michoacán, seemingly is confined to southwestern Mexico. Our specimens extend its known range south at least to central Guerrero and are the first records from that state. The hairy fruit bat is essentially a slightly smaller (weight of males, 39 gr., of one female, 47 gr.) form of *A. jamaicensis* except that the uropatagium is densely haired and the shape of the frontal region of the skull is different (see remarks under

A. jamaicensis). It is distinctive from *A. cinereus*, the next smaller fruit bat, by its larger size (forearm 52-57 mm. as opposed to 45-46 mm.), possession of a mantle, interfemoral membrane well-furred, and underfur nearly bicolor. In addition, our collecting records indicate a distinct difference in altitudinal preference between the two. All our skulls of *A. hirsutus* from central Guerrero have the minute third upper molar present.

Two of our three specimens of *hirsutus* were taken in a large humid cave near Colotlipa, where they occurred with *Balantiopteryx*, *Glossophaga*, and *Natalus*. The other was found under a boulder on a hillside near Tierra Colorada, which site it was using as a daytime retreat. Both of these localities are in the Tropical Deciduous Forest.

Specimens examined, 3, as follows: 4 mi. N Colotlipa, 3,000 ft., 2; 1 mi. SW Tierra Colorada, 900 ft., 1.

Artibeus jamaicensis jamaicensis Leach.—Twenty-three of our fruit bats are referable to the species *A. jamaicensis* on the basis of the classification employed by Hershkovitz (1949) and Dalquest (1953*b*). A large *Artibeus*, intermediate in size between *A. hirsutus* and *A. lituratus*, *A. jamaicensis* is exceeded in size only by the latter in this genus. The forearm is relatively long, average 58 mm., rarely 56 or 61, and the skull is large, condylocanine length averaging 24.0 mm., seldom 23.6 or 24.6. The only exception in our series, one which may be a subadult individual, is a female that has a condylocanine length of 23.3 mm. Males and females seem to be about the same size except that males average slightly heavier (43.6 gm.) than non-gravid females (38.5 gm.). No sexual or age dichromatism is evident.

From a morphological standpoint, there seems to be little that is unique about *jamaicensis*, and the features which separate it from the other large members of the genus (principally *hirsutus* and *lituratus*) are mostly characters of combination and degree rather than kind. The mantle of the neck and shoulder region of *jamaicensis* is lighter in tone than the general coloration of the back and rump, a character which it shares with *hirsutus* and *lituratus*. Moreover, the general tone of the body color seems to be about the same as that in males of *lituratus*. Comparison of *jamaicensis* with specimens of *hirsutus* from Morelos and northern Guerrero shows that the latter is lighter in color, but our specimens of *hirsutus* from central Guerrero do not show this trait. The facial stripes are either indistinct or absent as they are in *hirsutus*. For a further comparison of *jamaicensis* and *lituratus*, see remarks under *A. lituratus*.

The Jamaica fruit bat differs from *hirsutus* in having an almost naked interfemoral membrane; that of *hirsutus* is comparatively well furred. A difference in the shape of the frontal region of the skull also seems to be constant in our specimens. In *jamaicensis*, there is a pronounced naso-frontal depression just anterior to the sagittal crest which contrasts with the slightly concave surface of the frontal region in *hirsutus*. Moreover, the ridges which extend outward from the front of the sagittal crest and the supraorbital ridges meet in an oblique angle at the postorbital process which gives the whole nasal region of the skull an expanded, flattened appearance. The ridges from the

sagittal crest to the postorbital process are faint in *hirsutus*, and together with the supraorbital ridges they form nearly a straight line. Consequently, the frontal region of the skull of *hirsutus* does not have the laterally expanded, angled appearance of *jamaicensis*. Comparison of Guerreran *jamaicensis* with *hirsutus* from Morelos shows the same cranial differences. The size relationship between the two reported by Dalquest (1953*b*) is apparent in only two of our three *hirsutus*.

As Dalquest (*op. cit.*) points out, the characters which separate *hirsutus* from *A. jamaicensis* "are of the magnitude which usually separate subspecies." Their ranges in Guerrero may eventually be shown to overlap, but we have not taken both at the same locality. Neither do we know if there is a habitat difference. Part of the solution of the taxonomic relationships between the two forms will most certainly involve an analysis of their respective habitat preferences.

This is probably the most common species of fruit bat in Guerrero. Two were caught in a "mist" net set over a stream; the others were either netted or shot in and near caves. Males and females were taken together in the same cave which they occupied with *Micronycteris*, *Glossophaga*, *Desmodus*, and *Natalus*. It is interesting to note that on one occasion when the bat net was set across the entrance of a cave one evening, Jamaica fruit bats were trying to enter the cave and struck the net from the outside.

All of our specimens have the "evanescent third upper molar," a character which is, as Hershkovitz (1949) suggests, apparently of little more than local significance. The lengths of the testes of six adult males collected from June 9 to June 14 range from 7 to 11 mm. and average 8.6. None of the females collected during the same period was pregnant, a condition which suggests a difference in breeding habits from *A. lituratus*.

Specimens examined, 25 as follows: Acahuizotla, 2800 ft., 23; Papayo, 1 (B.S.C.); 18 km. S Taxco, 1.

Artibeus lituratus palmarum J. A. Allen and Chapman.—Hershkobitz (1949) has presented evidence to show that the larger "races" of *Artibeus* belong to a distinct species, *A. lituratus*, and are not simply larger forms of *A. jamaicensis* as Andersen (1908) thought. Our study of series of specimens of both the larger and smaller "races" of *Artibeus* from Guerrero indicates the correctness of this conclusion, and we follow Hershkovitz in this regard.

A. lituratus is the largest of the fruit bats inhabiting Guerrero. In adult animals the forearm is long, 62 to 70 mm. (average 65), and the skulls are large, condylocanine length 24.6 to 26.7 (average 25.5). Males weighed from 54 to 58 gr.; females (gravid), 46 to 72, averaging 67. A juvenile and a subadult, both females, have forearms of 61 and 62 mm. and condylocanine lengths of 23.9 and 23.8 mm., respectively. One adult male (TCWC 5345), from Acahuizotla, probably an aberrant individual, is worth special mention since it is not included in the measurements. It is an exceedingly small *lituratus* whose external and cranial measurements more closely approximate those

of *jamaicensis*. In other characters (color of pelage, hairiness of the interfemoral membrane, and conformation of the frontal part of the skull) it is typically *lituratus*.

Besides their larger size, our Trinidad fruit bats are also distinctive in several other ways. Facial stripes, which are long, whitish, and well defined, extend from the base of the noseleaf up over the top of the head between the anterior edges of the ears. An indistinct infraorbital light stripe is also usually present. There is a tendency for the uropatagium to be more hairy than in some other species of *Artibeus*, but this is not considered by us to be a stable character.

There is pronounced sexual dichromatism in our series, a difference we have not seen mentioned in the literature. All of our adult females, save one which is colored like the males (TCWC 5139), exhibit a lighter, brighter, more reddish coloration throughout than the males. In all of our material the lighter colored region on the neck and shoulders contrasts with the back and rump, and the striking color dissimilarity between males and females is most distinctive there. As a result, the mantle is not so apparent in males as in females.

Andersen (1908) comments on dark-colored and light-colored "types" which he interprets as primarily the result of age, the older individuals being the lighter. Our specimens show no apparent correlation between age and color except that younger individuals evidence a pelage similar in color to adult males. The one female noted above as male-like in coloration is, on the basis of tooth wear, an old adult.

A. lituratus differs from *jamaicensis*, which closely resembles it, in several ways. The underfur in *lituratus* is unicolor, at most darker tipped, whereas in *jamaicensis* the belly fur is almost bicolored, distinctly silvery tipped. The facial stripes are much more distinct in *lituratus*; indistinct or absent in *jamaicensis*. Cranially, the supraorbital and antorbital ridges are well developed and sharp-angled forming a lateral extension to the nasofrontal depression in *lituratus*. They are comparatively less well developed in *jamaicensis*. In addition, skulls of *lituratus* possess a pair of raised ridges running at an angle across the frontals from the front of the sagittal crest to the postorbital process. The same ridges are apparent in *jamaicensis* but to a lesser extent. The postorbital processes of *lituratus* are more prominent and pointed than in *jamaicensis*, at least in the older specimens. In all but one of our specimens the skulls and forearms of the smallest *lituratus* are larger than the largest *jamaicensis*. A character of questionable value is the presence of a third upper molar in all of our specimens of *jamaicensis* and its complete absence in *lituratus*. No emphasis is placed by us on the relative hairiness of the interfemoral membrane in comparing these two species.

All of our specimens were obtained from caves as they hung singly or severally in the exposed entrances where no artificial light was needed to shoot them. The ones we encountered were rather shy, flying when we approached

the mouths of the caves they occupied. Their preference for forested habitats is indicated both by the locations in which they were collected and by their frugivorous food habits (see Dalquest, 1953*a*).

The testes of six adult males, all taken June 9 to 14 at Acahuizotla, ranged from 7 to 11 mm. in length. Eight adult females taken at the same locality June 17 were all pregnant. Each female contained only one fetus that ranged from 10 to 35 mm. in crown-rump length. Since two younger individuals of differing ages were collected along with the gravid females, the inference is that these bats may breed over an extended period during the spring of the year.

The Trinidad fruit bat has formerly been recorded in Mexico from Veracruz and Jalisco (Andersen, 1908) and San Luis Potosí (Dalquest, 1953). Our specimens, the first records from Guerrero, mark a range extension for this species in Mexico.

Specimens examined, 19, as follows: Acahuizotla, 2,800 ft., 14; Colotlipa, 2,700 ft., 1; Papayo, 25 ft., 4.

Artibeus cinereus toltecus (Saussure).—Our only record for Guerrero is that of a male weighing 15 grams that was caught at night in a bat net set across a tree-lined stream 17 kilometers south of Taxco, at an elevation of 4,000 ft. The forearm measures 39 mm.; greatest length of the skull, 20.2 mm.

In our experience, *A. c. toltecus* is not only a bat of the tropical lowlands, but also of the semi-arid parts of the interior of Mexico (Tlaxcala and the Balsas Basin of Guerrero), whereas *A. c. aztecus* is known only from the coniferous forest areas at high elevations. Consequently, we do not concur with Dalquest's (1953*b*) statement that *aziecus* "is the race of *cinereus* found on the semi-arid Mexican Plateau."

Artibeus cinereus aztecus Andersen.—This small, rare fruit bat was described by Andersen in 1906 on the basis of specimens taken at Tetla del Volcan, Morelos. Subsequently four other examples were later taken from a cave on Cerra Companaria, San Luis Potosí (Dalquest, 1953*b*). Our four *additional* specimens extend the range of the little fruit bat south in Mexico into Guerrero. We follow Dalquest in placing *aztecus* as a subspecies of *A. cinereus*.

A. c. aztecus is a large race of *cinereus* which can be identified by the following characters: forearm, 44 to 46 m.; condylocanine length, 19.3 to 20.4 mm.; weight, 23 to 25 gr.; color, dark brown, facial stripes present but indistinct; interfemoral membrane rather densely furred, both above and below; underfur unicolored; uropatagium relatively narrow for *Artibeus*, but similar to that in *Sturnira*. The identification of our specimens is based on comparison with paratypes of *aztecus*.

The little fruit bat seems to be a cave dweller that prefers heavily forested situations at high altitudes. Three of our specimens are adult females; the other, a young male. They were found hanging together in a crevice high up on the steep, rock face of a sink hole in the Cloud Forest near Omiltemi.

These bats were taken about 3:00 p.m. A number of others were present at the same time, but we managed to collect only the four.

Specimens examined, 4, from 2 mi. W Omiltemi, 7,900 ft.

Artibeus nanus Andersen.—This dwarf fruit bat is the smallest member of the genus *Artibeus* in Mexico. A single male with large testes was caught December 31, 1956, in a bat net set in a grove of cocoanut palms and banana trees near El Papayo. It weighed 10.5 grams and has a forearm 35.3 mm. in length; greatest length of skull, 18.4; zygomatic width 11.6. It differs from other small *Artibeus* in having a pair of conspicuous, broad, white facial stripes, pale margins on the ears, and a comparatively large nose leaf. This is the second locality record for Guerrero and the first specimen to be taken in the last 50 years.

Specimen examined, 1, from El Papayo, 25 ft. Additional record: Tierra Colorada, 900 ft., 3 (Andersen, 1908).

Desmodus rotundus murinus Wagner.—The common vampire bat is widespread in the lowland areas of Guerrero, but it probably does not range into the higher mountains. Most of our specimens were taken in deep, dark caves which they were using as daytime retreats. Two examples taken near Mexcala, but not saved, and one near Taxco were caught at night in a bat net. Near Mexcala the net was set in the bushes beside our camp, and the bats struck it about three feet from the ground. Since the net was checked and found empty at 11:00 p.m. the night before, these bats seemingly are active far into the night, or at least prior to dawn. Near Taxco the net was placed across a tree-lined stream.

D. rotundus is gregarious. Large colonies often occupy a cave and, contrary to the habits of many kinds of bats, adults of both sexes often occur together in the same colony throughout the year. In the cave near Mexcala, these bats were collected along with *Chilonycteris* and *Macrotus.* Near Acahuizotla, vampire bats were found in the same cave with *Glossophaga* and *Natalus.* The latter cave was also used only at night by large numbers of *Artibeus jamaicensis.* Judging from the accumulation of excreta, both at Mexcala and Acahuizotla, these caves are probably used throughout the year.

About half of the specimens taken at Acahuizotla in mid-June were subadults or juveniles. The testes of one adult male taken June 20 measured 8 mm. in length, and those of another taken December 23 were 9 mm. long. Although the vampire bat may bred throughout the year as Dalquest (1953*a*) suggests, none of our adult females taken in June was pregnant; nor was the single adult female collected in December.

Specimens examined, 49 as follows: Acahuizotla, 2,800 ft., 19; Cañon del Zopilote, 16 km. from Río Balsas, 2,100 ft., 1; 3 mi. W Mexcala, 2,000 ft., 2; 17 km. S Taxco, 4,000 ft., 1; Papayo, 26 (B.S.C.). Additional records: 5 mi. NW Acapulco, 2 (Torre, 1955); 6 km. N Cuetzala del Progreso, 35 (Martinez and Villa, 1940).

Natalus mexicanus mexicanus Miller.—Funnel-eared bats are known to

have an extensive range in Central America and Mexico with one subspecies (*mexicanus*) occurring in northwestern Mexico and a second (*saturatus*) occupying the Gulf coast from southern Tamaulipas in the north at least to Campeche in the south. Since *N. mexicanus* has not previously been recorded from southwestern Mexico, the collection of seven specimens from Guerrero is of considerable interest.

Several kinds of mammals have parallel distributions along the Pacific and Gulf coasts of Mexico, and on geographic grounds it would not be unreasonable to expect that examples of *N. mexicanus* from Guerrero would belong to the subspecies *saturatus*. Moreover, cranial and external measurements of our specimens are remarkably similar to those recorded by Dalquest and Hall (1949) for that race. However, our specimens from Guerrero differ from *saturatus* in color. Davis compared our specimens with *saturatus* from Veracruz and referred them to the subspecies *mexicanus* with the following comment:

"Compared with paratypes of *N. m. saturatus* Dalquest and Hall, from Veracruz, these specimens are much closer to pale sooty brown in color rather than amber brown or chestnut; also the skull is noticeably smaller, especially the cranium. One of our specimens matches the one "gray phase" specimen (K.U. no. 17845) of *saturatus* reported by Dalquest and Hall (1949); three of the others are paler, the other one is paler underneath but darker (sooty) above."

The specimens from Acahuizotla were shot in a small cave in a limestone bluff a short distance east of the village. The two from near Colotlipa were taken during the daytime in a large, humid cavern which *Glossophaga* and *Artibeus hirsutus* also were using. In the latter cave, the funnel-eared bat was conspicuous by its small size and striking color, and even with artificial light it could readily be recognized among the hundreds of other bats hanging from the ceiling. These were the only two seen there. *N. mexicanus* may be restricted to lower elevations in the Tropical Deciduous Forest.

Specimens examined, 7, as follows: Acahuizotla, 2,800 ft., 5; 4 mi. N Colotlipa, 3,000 ft., 2.

Myotis fortidens Miller and Allen.—Only two specimens of this species have been recorded from Guerrero, both of which were collected at Papayo in 1903 by Nelson and Goldman. This species occupies the arid tropical sections of southern and western Mexico (see Hall and Dalquest, 1950).

Eptesicus fuscus miradorensis (Allen).—Two adult females and one juvenile male were caught at night in a bat net which was stretched across a cypress-lined stream along which several species of bats foraged each night. One female, taken the night of June 11, had a half-grown juvenile male attached to her breast. Weights of the two adults, 18 and 19.5 grams; length of forearm, 51 and 52 mm.

Specimens examined, 3, all from 17 km. S Taxco, elevation 4,000 ft.

Dasypterus ega xanthinus Thomas.—On December 30, 1956, a single individual was shot from the fronds of a cocoanut tree at El Papayo where

it was roosting in company with *Molossus sinaloae*. This specimen, a male, weighed 12.5 grams and has the following measurements: Total length, 112; tail, 54; foot, 10; ear from notch, 17; forearm, 46.7; greatest length of skull, 15.8. This bat has not been reported previously from Guerrero.

Rhogeessa parvula tumida H. Allen.—The occurrence of the little yellow bat in Guerrero is based on one specimen from Amula (= Almolonga) recorded by Miller (1897). Apparently there are no additional records for the state. It probably will be found to be a relatively common bat in the tropical thorny scrub forests of southern Guerrero when adequate techniques of capture are employed (see Dalquest, 1954). In view of Hall's (1952) recent review of these bats in Mexico, the allocation of the above record to *tumida* is open to question.

Tadarida mexicana (Saussure).—The Mexican free-tailed bat is widespread over much of Mexico and is probably much more numerous in Guerrero than our meager data indicate. Large flights of bats, presumably all of this species, flew over our camp near Almolonga each evening after sunset. These bats were flying a relatively straight course about 20 feet from the ground and appeared to be coming from a small rocky hillside a short distance away; however, they may have come from the village of Almolonga. Since *T. mexicana* is known to occupy buildings, as well as caves, our neglect of bats in and near towns may account for our failure to take more examples of this species.

Our single specimen, an adult female, containing one embryo 53 mm. in crown to rump length, was shot an hour after sunset on June 29.

Specimen examined, 1, from 2.5 mm. S Almolonga, 5,600 ft. Additional record: Mexicopan (suburb of Teloloapan) (Martinez and Villa, 1940).

Molossus sinaloae Allen.—These bats were rather common in December, 1956, at El Papayo where they roosted among the dead, drooping fronds of cocoanut palms. Only a few palms fail to shed their fronds and only those trees that had a large cluster of dead fronds harbored bats whose presence could be ascertained by the presence of bat feces on the ground below the cluster. Two adults, a male and a female, were dislodged and captured by hand from one tree which also served as a daytime roost for *Dasypterus ega*; a third was caught just after dark in a net stretched between two palm trees. This bat hit the net about two feet above the ground. All three were excessively fat, weighing 25, 32, and 33 grams; none was in breeding condition.

Specimens examined, 3, from El Papayo, 25 ft. Additional record: 5 mi. NW Acapulco, 9 (Torre, 1955).

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LIFE HISTORY AND ECOLOGY OF *MYOTIS AUSTRORIPARIUS* IN FLORIDA

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Bats of the species *Myotis austroriparius* are remarkable for their disjunct distribution. The three races of this species are found in widely separated geographical areas which differ greatly in environmental conditions. *Myotis a. mumfordi* occurs in south-central Indiana (Rice, 1955*a*), in extreme southern Illinois (Smith and Parmalee, 1954), and in central Arkansas (Davis *et al.*, 1955); *M. a. gatesi* occurs in Louisiana (Lowery, 1943); and *M. a. austroriparius* occurs in Florida, Georgia, and Alabama. This wide distribution has offered an excellent opportunity to determine how behavior, social organization, and population dynamics have been modified to meet the varying ecology of this species.

Virtually nothing has been published on the natural history of *Myotis austroriparius*. The present study was undertaken to determine the general features of the life history and ecology of these bats. The field work on which this report is based extended from February 1953 to June 1955. Besides shooting, mist-netting, and collecting in outside roosting sites, I visited every known cave colony of bats in Florida. In addition, data recorded by the Florida Speleological Society prior to this investigation were available to me. I have observed well over a million bats in the field, and have individually examined 13,169 for sex, age, reproductive condition, parasites, and other data. Numbered bands were placed on 2,751 bats, from which 706 returns, repeats and recoveries were obtained by the end of 1955.

Acknowledgments.—I am indebted to the officers and members of the Florida Speleological Society, especially Robert B. Cumming, Richard Bennett, and Donald Martin, for their fine cooperation and assistance in the field. The following students and faculty members of the University of Florida Department of Biology have aided me in the field on numerous occasions: David K. Caldwell, Edwin H. McConkey, H. B. Sherman, Gerald E. Simon, Bette A. Starner, and John W. Twente. William L. Jennings, who is studying the problem of rabies in bats for the Florida State Board of Health, cooperated in much of the field work, and has been most helpful in obtaining banding returns since my departure from Florida. The following individuals have kindly furnished me much comparative data on *Myotis austroriparius* in other parts of its range: George H. Lowery, Jr. (Louisiana); John A. Sealander, Jr. (Arkansas); Philip W. Smith and Wayne H. Davis (Illinois); and Russell E. Mumford (Indiana). H. B. Sherman and John W. Twente, Jr., offered much valuable advice and criticism throughout the study, and read the manuscript.

DISTRIBUTION

Myotis a. austroriparius is restricted to the vicinity of the caverniferous karst regions of Florida and adjacent parts of Georgia and Alabama. There are two apparently somewhat isolated populations. One is in north peninsular Florida

from Suwannee and Hamilton Counties southeast along the central uplands to Orange County, and south along the Gulf Coast lowlands to Tampa Bay. There is one report from Key West (Hamilton, 1943), but I have been unable to trace the source of this record, and if valid it represents a straggler, as *Myotis* has never been reported otherwise from the southern portion of the Florida peninsula (Albert Schwartz, *in litt.*). The other population is in west Florida from Jackson County east to Jefferson County, and south to the Gulf Coast; this same population extends north into southwestern Georgia (Quay, 1949) and south-central Alabama (Wayne H. Davis, *in litt.*). All of the known stations of occurrence of this species in Florida are plotted on the accompanying map (Fig. 1).

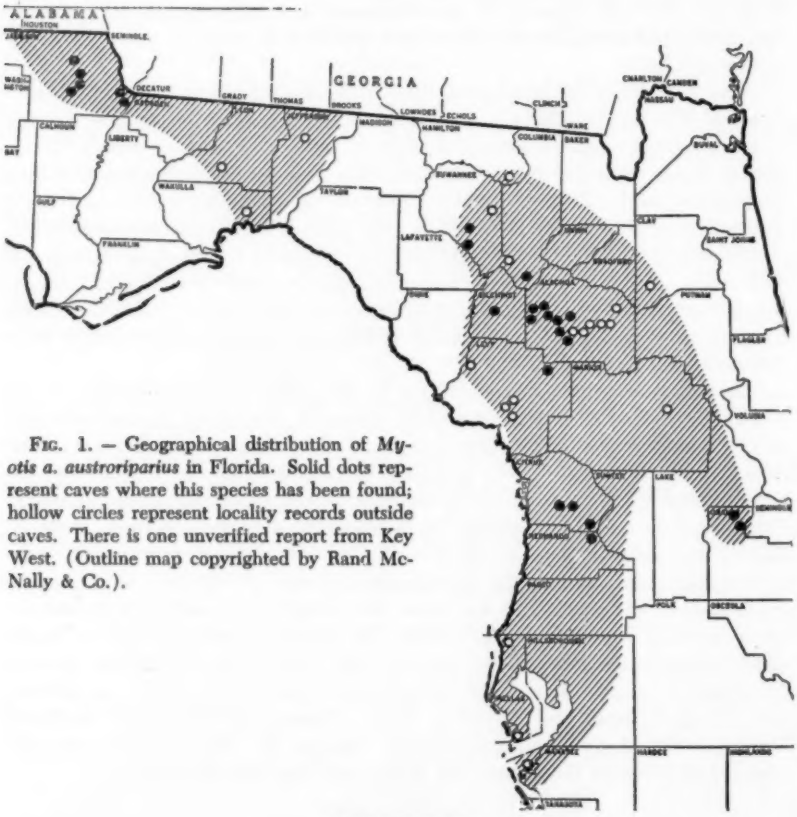

FIG. 1. — Geographical distribution of *Myotis a. austroriparius* in Florida. Solid dots represent caves where this species has been found; hollow circles represent locality records outside caves. There is one unverified report from Key West. (Outline map copyrighted by Rand McNally & Co.).

LIFE HISTORY

Myotis austroriparius is predominantly a cave bat, and in the upper Mississippi valley its life history is essentially the same as that of most of the other

northern cave-inhabiting species of *Myotis*. In west Florida it follows the same general life-history pattern as in Indiana and Illinois. However, in peninsular Florida its life history shows a number of adaptations to the subtropical climate. Unfortunately, practically nothing is known of the life history of the Louisiana race; it probably differs considerably from that of the other races, as it lives in a region where there are no caves.

Winter habits.—The upper Mississippi valley and west Florida populations remain in fairly large colonies in caves during the winter. In Indiana they have been found hibernating in caves during seven months of the year, from September to March. In West Florida they hibernate for only about four or five months, from late October until probably early March. They probably remain torpid for most of the time during the winter, as there is no indication that they leave the caves to feed at that season.

In contrast, in peninsular Florida they remain active throughout much of the winter and feed regularly. They may become dormant for short periods during cold spells, but they do not go into prolonged hibernation as they do farther north. During this season the vast majority of them have left the caves, and they do not gather into large clusters, but roost in small groups, or occasionally singly, in various outdoor sites.

Breeding season.—One of the most remarkable features of reproduction in many northern species of vespertilionid bats is that copulation occurs in the autumn, and the sperm are stored in the uterus until the occurrence of ovulation, which is delayed until spring. This is apparently an adaptation to the long period of winter dormancy, and it is doubtful if it could take place in bats which do not remain torpid during most of the winter. Consequently it would be expected that the population of *Myotis austroriparius* occupying peninsular Florida would have a later breeding season than that in the upper Mississippi valley and in west Florida.

The breeding season of *Myotis austroriparius* was determined by examining the epididymides of the males. Enlarged epididymides indicate the presence of sperm, and most of the copulation is assumed to occur when the majority of males have enlarged epididymides.

I have examined specimens collected in Illinois on November 29 and December 2 which had enlarged epididymides. In Indiana, R. E. Mumford found a group of these bats on November 23 which he believes had been copulating. Therefore most of the copulation in this area probably occurs in the autumn, as with other northern species of *Myotis*. That some mating occurs in the spring, however, is indicated by an Indiana specimen with enlarged epididymides collected on March 2. The year-old females are probably fertilized at this time, as they are not generally believed to mate in the autumn. Guthrie (1933) has found a similar limited spring mating period for *Myotis lucifugus* in Missouri.

In west Florida, the majority of males have enlarged epididymides from October 30 to December 11. I do not know whether they may mate again in the spring after hibernation, but if the females bear young at the age of one year, as they do in peninsular Florida, such a spring mating season probably

occurs.

In peninsular Florida, a few males may be found with enlarged epididymides as early as November 1. Virtually all males have enlarged epididymides from February 12 to April 16. After May 4, practically no males have enlarged epididymides. Thus it seems that the peninsular Florida population has largely abandoned an autumn mating season in favor of a spring one. Mating may occur either before or after the bats have congregated at the maternity caves, as groups of bats containing males with enlarged epididymides have been found roosting both outside and in caves.

Arrival at the maternity colonies.—In Florida, during the spring and summer, practically all of the females, along with some of the males, congregate in certain caves to bear their young. They begin to arrive at these maternity caves about the second week in March. At Bat Cave, Alachua County, for example, the first bats were seen on March 14 in 1953, on March 13 in 1954, and on March 19 in 1955. By the end of March or the first of April the breeding population has reached its peak in these caves. During this time there is a very marked decrease in the number of bats found occupying roosting sites outside caves. Maternity colonies contain anywhere from about 2,000 to 90,000 adult bats. The bats gather in very large, dense clusters, averaging slightly over 150 bats per square foot of ceiling.

While the pregnant females and some of the males are gathered in the maternity colonies, the majority of the males and the non-breeding females remain apart from the maternity colonies. Either they form separate colonies in other caves, as in west Florida; or they roost singly or in small groups outside caves, as in peninsular Florida. In the latter area, the males show an increased tendency to roost in the caves during the middle of the summer.

Birth of the young.—Parturition in *Myotis austroriparius* has been described by Sherman (1930).

The time during which birth occurs in Indiana and Illinois is unknown, but it doubtless occurs in late June, as with other species of *Myotis* in those latitudes.

Because of the earliness of spring in west Florida, parturition there occurs about six weeks earlier than it does in the north, and only slightly, if at all, later than in peninsular Florida. On May 8 and 9, 1954, all of the pregnant female *Myotis austroriparius* in Mud Cave, Jackson County, were about to give birth. A few young had already been born. A few cases of parturition were observed in the cave, and several captive females gave birth to young that night. The population of *Myotis grisescens* in west Florida shows a similar advance in the season of parturition over that in the midwest (Rice, 1955*b*).

In peninsular Florida, parturition extends from the end of April until late May, with the peak occurring about the second week of May. April 30 was the earliest date on which young bats were found. No pregnant females were found after May 17.

The females do not carry their young with them when they leave the caves at night. The older young form clusters by themselves in the caves when the

adults are out feeding. The young are able to fly five or six weeks after birth. The earliest date on which young have been found able to fly was June 9. The latest date on which young bats still unable to fly have been found was July 3.

Dispersal from maternity colonies.—In west Florida, toward the end of October, there is a marked decrease in the number of bats in the maternity colonies, and a marked increase in the number in the winter colonies, as compared with spring populations.

The number of bats in the peninsular Florida maternity colonies begins to show a decided decrease in the last half of October, and by the second week in December, the maternity colonies are completely deserted, except for a few bats which may remain in some of the larger maternity colonies all winter. The males tend to leave the caves earlier than the females, their numbers decreasing as early as September. Concomitant with the departure from the maternity caves, the bats begin to appear in larger numbers in habitual outside roosting sites.

HABITAT SELECTION

Habitat selection behavior of bats is one of the most important factors of their survival. Except when modified by the social behavior of clustering, the body temperature, and thus the metabolic rate, of resting bats is dependent on the temperature of their environment. The behavior patterns of bats are adapted to provide optimum body temperatures for most efficient metabolism during periods when the food supply is plentiful, and to adjust the metabolic rate to the available food supply during periods of food scarcity. (Twente, 1955.)

The continental climate of west Florida presents the population of *Myotis austroriparius* in that region with problems of habitat selection essentially the same as those faced by most temperate zone cave bats, such as *M. a. mumfordi* in Indiana and Illinois. However, in the subtropical climate of peninsular Florida the environmental conditions are quite different from those in more northerly regions.

Summer roosting sites.—With the exception of *Myotis austroriparius gatesi* of Louisiana, which occurs in a region where there are no caves, *Myotis austroriparius* is predominantly a cave-dwelling bat, resembling in this respect *Myotis grisescens* and *Myotis velifer*.

The summer roosting sites of *Myotis austroriparius mumfordi* are probably in caves, as are those of the west Florida population of *Myotis a. austroriparius*, which they seem to resemble in most aspects of their ecology. They have been found in caves as late in the spring as April 17 in Indiana, April 7 in Illinois, and May 15 in Arkansas; and as early in the autumn as August 2 in Indiana and August 6 in Illinois. One was found in a cluster of 200 *Myotis lucifugus* in a house in Indiana on August 30 (R. E. Mumford, *in litt.*); two colonies of what may have been *Myotis austroriparius* were found in houses in southern Illinois in late summer (P. W. Smith, *in litt.*). It would not be too surprising if *Myotis austroriparius mumfordi*, at times at least, formed maternity colonies in buildings. The caves within their range are 10° to 20° F. cooler than Florida caves,

and outside situations with their warmer, but more variable, summer temperatures might provide a better environment at that season than would the caves with their relatively cool, but more stable, temperatures.

The population of *Myotis a. austroriparius* inhabiting west Florida is predominantly cave-inhabiting during the summer. Except for one colony found in a building, these bats have not been found roosting outside caves during the summer in that region. During the summer the west Florida caves provide the warm, uniform environment in which metabolic activities can proceed most efficiently.

In peninsular Florida, they also roost in caves in the summer, but not to such a great extent as the west Florida population. At this season, the majority of males are roosting outside the caves. The situations occupied by the males and non-pregnant females are about the same as those which they occupy during the winter. During the hottest weather in July and August, a larger proportion of the males resort to the cave colonies, probably because of the cooler temperatures to be found in the caves.

The females resort almost exclusively to caves to bring forth their young. Caves are apparently essential for this species in Florida. They may occasionally bear young outside caves, as evidenced by the finding of several females with young among a colony of 10,000 *Tadarida brasiliensis cynocephala* in a building (Sherman, 1937). Even though they do breed in buildings occasionally, they are apparently unable to maintain a self-sustaining colony outside of caves, because they do not occur very far beyond the limits of the caverniferous karst regions of Florida.

The caves of Florida are parts of a subterranean drainage system, dissolved out of the Eocene Ocala Limestone, which open to the surface through vertical chimneys. Most of them are still in the process of formation, and contain submerged portions which are often of greater extent than the emerged portions. The water table is usually 20 to 70 feet below the surface. These caves present a very uniform environment, in contrast to the caverns studied by Twente (1955) in Kansas and Oklahoma. The relative humidity in those caves that contain water is always between 99 and 100 per cent. The temperature in the deeper portions is practically constant the year round, varying from 73° F. in the latitude of Citrus County to 68° F. in the latitude of Jackson County. In some of the bat caves summer temperatures may reach 80° F., apparently because of the heat produced by the large bat colonies.

Cave sites occupied by maternity colonies of *Myotis austroriparius* all have two characteristics in common: (1) they contain permanent bodies of water, and (2) they have a large area of horizontal ceiling at least six feet above the water. Narrow passages, rooms with low ceilings, and rooms with dry floors are never used as regular roosting sites by maternity colonies. Other than these two requirements, the caves may vary to any degree; some colonies occupy fairly light twilight zones, others are in total darkness. The requirement for water and a high ceiling seems to be a protection against climbing predators. The water may also be important in maintaining the uniformly high humidity;

in captivity, without drinking water, these bats quickly die of desiccation if not kept in a saturated atmosphere. In four instances in which a maternity colony deserted a cave, the desertion was correlated with a drop in the water level, causing the disappearance of the bodies of water below the roosting sites occupied by the colonies.

Winter roosting sites.—The cool winter temperatures and resulting scarcity of flying insect food confront the populations of *Myotis austroriparius* in Indiana, Illinois, Arkansas, and west Florida with the problem of maintaining a low enough metabolism throughout the winter so that the fat reserves are not used up before the end of the hibernating season; at the same time they must avoid fatal freezing temperatures (Twente, 1955). This problem is met by spending the winter in caves.

In Indiana, Illinois, and Arkansas, these bats have been found only in caves and mines during the winter. Winter temperatures in the caves of those regions are between 40° and 50° F., low enough to maintain torpidity for fairly extensive periods throughout the winter, whereas outdoor temperatures are below freezing much of the time, rendering outside roosting sites untenable. In this respect *Myotis austroriparius* behaves as other temperate zone cave bats.

In the west Florida region also, they usually spend the winter in caves, or occasionally in buildings. The caves of this region are warmer than those in the upper Mississippi valley, winter temperatures averaging 65° to 68° F. in the deeper portions. Outdoor temperatures frequently drop below freezing. These higher cave temperatures increase the irritability of the hibernating bats, resulting in a tendency for them to move to the cooler parts of the caves, or to cooler caves. In some of these caves winter temperatures drop to between 50° and 60° F. in late December, January, and February. These low temperatures are due either to slight air currents in the caves, or to the shallowness of the caves.

In peninsular Florida, conditions are quite different. Flying insects are available, in somewhat reduced abundance, all winter, except during occasional cold waves. Therefore long periods of sustained torpidity are unnecessary. Moreover, the relatively high temperatures of 69° to 73° F. in most caves make them unsuitable for hibernation. As a result the great majority of the bats leave the caves during the winter. At this season they may be found in a great variety of non-cave situations, all of which are protected from climatic extremes, but more exposed than are the caves to cool temperatures during cold spells when it is essential to adjust the metabolic rate to the available food supply. During the winter they are usually found roosting over water in the crevices between wooden bridge timbers, in storm sewers, in road culverts, in the vertical drain pipes of concrete railroad bridges, and in boat houses. They have also been found roosting in houses and buildings. Like so many other species of bats they have found the structures of man ideally suited to their habitat requirements. They have also been found roosting in hollow, dead, black mangrove (*Avicennia nitida nitida*) trees. Hollow trees were probably

their original winter roosting sites.

Even in the winter, a few bats may be found in peninsular Florida caves, however. They have been found at this season in some of the larger maternity caves. None of them are torpid, however, and their roosting in these caves probably results from a strong attachment of some individuals to the "home" cave. However, there are certain caves which are more exposed to temperature fluctuations, to which small numbers of bats regularly resort during the winter. Temperatures recorded in these caves from November to March varied between 58° and 64° F. These same caves are also used extensively by hibernating *Pipistrellus subflavus* during the winter.

Bats occupying these cooler caves are usually quite torpid, even during warm weather, as cave temperatures remain cool during such times, and the bats are much less irritable than bats found in different situations or at different seasons. Twente (1955) has described the function of winter clustering to maintain cool body temperatures by protecting the bats from warm air, allowing them to lose their body heat to the adjacent rock. In west Florida, *Myotis austroriparius* gather in just such a manner into large winter clusters of several hundred individuals each. In peninsular Florida they usually roost singly or in small clusters in the caves which they occupy during the winter; I have never seen more than sixty torpid individuals in one cluster in peninsular Florida. These bats are invariably roosting in depressions in the ceiling, in small solution pits, or in deep crevices. As a consequence of the small numbers present in the caves during the winter, they have had to solve the problem of avoiding contact with warm air in a different way than they have in west Florida, and in a manner similar to that of *Eptesicus fuscus* and *Antrozous pallidus* (Twente, 1955).

Feeding areas.—Other than that they feed on flying insects, as do other vespertilionid bats, nothing is known of the food habits of *Myotis austroriparius*. The few individuals collected in the statewide bat shoots by the Florida State Board of Health were all taken over water. From 8:00 to 11:30 P. M. on 15 May 1954, with the aid of a headlamp, I watched hundreds of these bats feeding along the Ichatucknee River in Columbia County; they were flying low over the water, never rising higher than two feet above the surface. William L. Jennings has reported similar feeding behavior at Newnan's Lake, Alachua County. After the evening flights have left the caves, many of these bats may be seen coursing low over the open fields near the caves.

Myotis austroriparius are late feeders. They do not leave the caves until well after sunset, and are not on the wing until the light is inadequate for shooting. Of some 800 bats collected during the past year by the Florida State Board of Health's bat shoots, only three *Myotis austroriparius* were taken.

POPULATION DYNAMICS

Population density.—In the upper Mississippi valley, *Myotis austroriparius* is by far the rarest member of the genus. No estimates of population densities can be made for those areas. It is also apparently very rare in Louisiana.

In contrast, in Florida it is extremely abundant. A fairly accurate minimum estimate of population density may be made for that portion of its peninsular Florida range north of 29°24′ N. The limits of its distribution are fairly well known in this area, and cover about 2000 square miles in southern Suwannee, southern Columbia, Gilchrist, Alachua, northern Levy, and northern Marion counties. Since the caves of this region are so well known, the majority, if not all, of the maternity colonies have been located. I have made estimates of the numbers of bats in each of these colonies. These estimates were made by measuring the number of square feet of cave ceiling covered by the clusters, and multiplying by a factor of 150 bats per square foot, which is about the minimum clustering density. The following figures indicate the number of adult bats present in each of these caves prior to the birth of the young in May:

The Devil's Head and Horns (Suwannee County)	2,500
Roberts' Cave (Gilchrist County)	6,000
Bat Cave (Alachua County)	2,500
Grant's Cave (Alachua County)	90,000
Hog Sink (Alachua County)	30,000
The Devil's Den (Levy County)	1,000

This gives an estimated total population in the caves of 132,000. This consists of 22 per cent males, but males actually make up 39 per cent of the total population. Making allowance for the males roosting outside the caves, the total population in this area may be estimated at 155,000. These figures suggest a minimum density of 77 *Myotis austroriparius* per square mile, or one

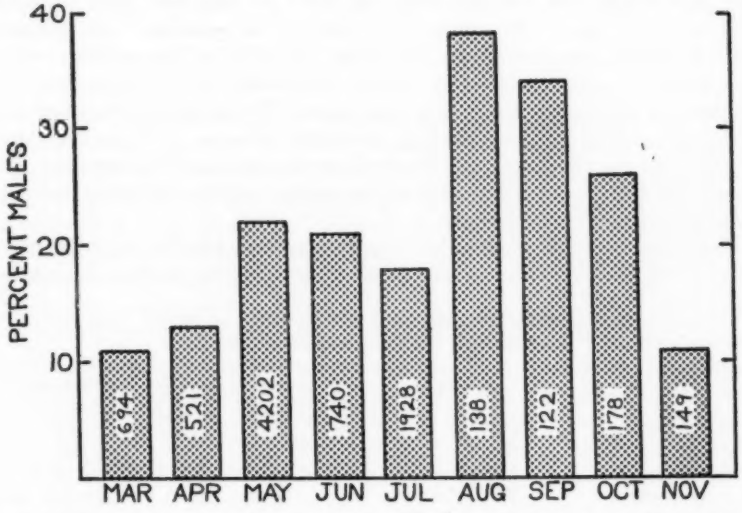

FIG. 2. — Sex ratios in adult population of *Myotis austroriparius* in peninsular Florida maternity colonies from March through November. Numbers indicate size of sample.

bat per 8.3 acres, during early May when the population is at its lowest point.

In July, when the young of the year are on the wing, the population would be increased by as much as 116 per cent. These 179,000 young bats would increase the total population of this area to 334,000. The density would be 167 bats per square mile, or one bat per 3.8 acres.

The only other published data on population densities of bats are Pearson, Koford, and Pearson's (1952) estimates for *Corynorhinus rafinesquei*: one bat per 310 acres on Santa Cruz Island, and one bat per 419 acres in Marin County, California.

Sex ratios.—The preponderance of females is an obvious feature of the maternity colonies. The adult sex ratio in peninsular Florida maternity colonies from March through November, based on examination of 8,672 adult bats, averages 18 per cent males; however, there is a marked seasonal variation (Fig. 2). When the bats first return to the caves in March, males comprise only 11 per cent of the population. There is a steady rise in proportion of males until August, when they make up 38 per cent of the total population. After early September, the ratio is influenced by the young of the year, which are no longer readily distinguishable in the field from the adults. However, this only tends to accentuate the fact that there is a decided decrease in the proportion of males in the early autumn.

The very meager data that I have from west Florida maternity colonies indicate a similar preponderance of females in that region.

A preponderance of females is to be expected in maternity colonies, so that sex ratios in such colonies cannot be considered representative of the population as a whole. Sex determinations on 377 bats examined from peninsular Florida caves during the winter, representing all months from November through March, revealed 42 per cent males. Of 108 bats from various roosting sites outside caves, examined in January, February, March, April, July, September and November, 30 per cent were males. The mean sex ratio of all adult bats in peninsular Florida, outside of maternity colonies, is 39 per cent males. This figure may be considered more truly representative of the sex ratio of the peninsular Florida population, and is comparable with the sex ratios derived in other parts of the species' range.

Examination of 728 *Myotis austroriparius* in west Florida, taken from winter cave colonies and non-breeding summer cave colonies in May, August, Sep-

TABLE 1.—*Geographical variation in adult sex ratios of Myotis austroriparius (data from maternity colonies excluded)*

RACE	LOCALITY	PER CENT MALES	SAMPLE SIZE
M. a. mumfordi	Indiana	71	77
M. a. mumfordi	Illinois	58	60
M. a. mumfordi	Arkansas	80	5
M. a. austroriparius	West Florida	43	728
M. a. austroriparius	Peninsular Florida	39	429
M. a. gatesi	Louisiana	25	8

tember, October, and December, showed 43 per cent males, a slightly higher proportion than in peninsular Florida.

In view of the apparent north to south cline of decrease in the proportion of males in many species of North American cave bats (Hitchcock, 1950), it is of interest to note that sex ratios of *Myotis austroriparius* in other parts of its range (Table 1) bear out this rule, varying from 71 per cent males in Indiana to 39 per cent males in peninsular Florida and 25 per cent males in Louisiana. It is not known whether this geographical variation is due to actual differences in sex ratios, or to differences in migratory behavior or roosting habits between the sexes. These data on *Myotis austroriparius* support the former theory, because the different populations are isolated, non-migratory, and represent three distinct races; also the difference in roosting habits between the males and females has been taken into consideration in calculating the sex ratios.

The sex ratio at birth is, as would be expected, virtually 1:1. Juvenile sex ratios in peninsular Florida are based on 2,847 young bats examined from May through September (Table 2). Juveniles are easily recognized by their pelage until September; during that month they molt into adult pelage. The over-all juvenile sex ratio is 51 per cent males.

TABLE 2. — *Juvenile sex ratios of Myotis austroriparius in peninsular Florida*

MONTH	PER CENT MALES	SAMPLE SIZE
May	41	41
June	50	988
July	51	1713
August	63	89
September	50	16
Mean	51	Total 2847

The disparity in the adult sex ratio may therefore be attributed to a higher death rate among males than among females. This is contrary to what has been found in more northern species of cave bats in both North America (Griffin, 1940) and Europe (Eisentraut, 1947). However, even the females have a higher death rate in Florida than they do farther north. This increased mortality of males may be due to their habit of roosting outside caves, and thus being exposed to more predation than are the females.

Age at sexual maturity.—In peninsular Florida, banding returns indicate that females, and probably males also, are sexually mature during the breeding season in the spring following the year of their birth. Apparently the majority of them become mature at this age, since there was very little difference in banding returns between juveniles and adults banded in the maternity colonies. At The Devil's Head and Horns, in Suwannee County, 300 juvenile females and 979 adult females were banded on May 11 and June 5, 1952. On May 2, 1953, 46 (15.3%) of the group banded as juveniles were recovered, as against 153 (15.6%) of the group banded as adults. All of these females were pregnant. On the same dates in 1952, 300 juvenile males and 419 adult males were

banded. On may 2, 1953, 25 (8.3%) of the group banded as juveniles were recovered, as against 42 (10.0%) of the group banded as adults. Unfortunately it was not possible to determine whether all of these males had been sexually active that season.

No data are available to show at what age females bear their first young in west Florida, where most of the mating apparently occurs in the autumn. If they behave as other northern species of *Myotis* (Guthrie, 1933), they probably bear young their first year.

Age group composition and survival rate.—All of the evidence indicates that the population of *Myotis austroriparius* in Florida is relatively stable from year to year. To remain stable, a population with an annual birth rate of 116 per cent must have a death rate of 54 per cent. The annual survival rate is equal to 100 per cent minus the annual death rate. Therefore, the annual survival rate of *Myotis austroriparius* in peninsular Florida would be 46 per cent. This is markedly lower than the annual survival rate of over 67 per cent in the more northern species of *Myotis* which never have more than one young per female, and in which the sex ratio is over 50 per cent males. This may be due to the fact that *Myotis austroriparius* is active practically the year 'round in peninsular Florida, and is thus exposed to predation for twelve months, while the more northern species hibernate for about seven months of the year, during which time many of their predators are also hibernating; northern bats are thus exposed to predation for only five months of the year.

From the annual survival rate, the theoretical age group composition, assuming a constant age-schedule of death rates, can be calculated as follows:

Year Class	Per cent of Population
1	54.0
2	24.8
3	11.4
4	5.3
5	2.4
6	1.1
7	0.5
8	0.3
9	0.2

By comparing actual age group compositions with the theoretical composition, it may be determined whether there is a difference in death rate among the various age groups.

Banding returns and sex and age ratio data from The Devil's Head and Horns in Suwannee County are adequate for determining the actual age group composition of one colony of this species. Allowance was made for adult males presumed to be roosting outside the cave. When the observed age group compositions are compared with the theoretical age group composition (Table 3), it may be seen that the second-year age group is slightly smaller, and the third-year-plus age group correspondingly larger, than the expected theoretical

values. This confirms Mohr's (1952) suggestion of an increase in survival rate among the older age groups of bat populations.

Birth rate.—Myotis a. austroriparius is the only North American form of *Myotis* which normally gives birth to two young. No data are available on birth rates in the other races of *M. austroriparius.* Data were gathered on 3,528 adult females with young or near-term fetuses. A week or two prior to parturition, the number of fetuses a female is carrying is easily determined visually or by feeling the abdomen.

During May, 1,489 pregnant females were examined; 1,343 were carrying two fetuses and 146 were carrying one fetus. One hundred and twelve adult females had 193 new-born young. This gives a ratio of 190 juveniles to 100 adult females in May. During June, 404 adult females accompanied by young were examined, and they had a total of 766 young. This gives a ratio for June of 190 juveniles to 100 adult females. By July there was a decided drop in the proportion. There were only 1,800 juveniles per 1,523 adult females examined, or a ratio of 118:100. By July the young are flying, and may leave the caves.

Since the peninsular Florida population consists of 61 per cent females, which bear an average of 1.90 young each, the annual birth rate is 116 per cent.

TABLE 3. — *Comparison of theoretical and observed age group composition of a population of Myotis austroriparius at The Devil's Head and Horns*

AGE GROUP COMPOSITION	1ST YEAR	2ND YEAR	3RD YEAR AND OVER
Observed May 2	54%*	17%	29%
Observed July 18	35%	21%	44%
Mean for Both Dates	47%	18%	35%
Theoretical	54%	25%	21%

* Includes fetuses

Home range.—Bats of the genus *Myotis* exhibit no territoriality, but they do maintain a definite, but rather large, home range, and have rather strong homing tendencies. Data from two sources reveal this home range instinct: (1) movements of marked individuals from the place of banding; and (2) homing experiments.

The great majority of banded bats that were recaptured were caught in the same cave in which they were banded. The percentage of recoveries was extremely low, compared with the number of repeats and returns. At The Devil's Head and Horns in Suwannee County, 1,998 bats of all ages were banded in May and June 1952; by the end of 1955, there were 617 repeats and returns, but only four recoveries. At Old Indian Cave, Jackson County, 142 adult bats were banded in October 1954; by the end of 1955, there were 14 repeats and no recoveries for this group. At Bat Cave, Alachua County, 166 juvenile bats were banded in June 1954; by the end of 1955, there were nine returns and eleven recoveries. This indicates a strong tendency for the adult bats to remain in or return to the same cave. The juveniles seem to have a greater tendency to wander.

TABLE 4. — *Movements of banded Myotis austroriparius which were recovered away from the cave in which they were banded*

SEX AND AGE	BANDED		RECOVERED		DISTANCE MOVED, MILES
	Date	Locality	Date	Locality	
♂ ad.	June 5, '52	Devil's Head and Horns	Jan., '54	Wellborn	15.00
♀ ad.	June 5, '52	Devil's Head and Horns	Jan., '54	Wellborn	15.00
♂ ad.	June 5, '52	Devil's Head and Horns	Mar. 17, '54	Wellborn	15.00
♀ juv.	June 19, '54	Bat Cave	July 31, '54	Grant's Cave	9.25
♀ juv.	June 19, '54	Bat Cave	July 31, '54	Grant's Cave	9.25
♀ juv.	June 19, '54	Bat Cave	July 31, '54	Grant's Cave	9.25
♂ juv.	June 19, '54	Bat Cave	Nov. 14, '54	Road Cave	4.50
♂ juv.	June 19, '54	Bat Cave	Nov. 14, '54	Road Cave	4.50
♂ juv.	June 19, '54	Bat Cave	Nov. 14, '54	Road Cave	4.50
♂ juv.	June 19, '54	Bat Cave	Nov. 14, '54	Road Cave	4.50
♀ juv.	June 19, '54	Bat Cave	Nov. 14, '54	Road Cave	4.50
♂ juv.	June 19, '54	Bat Cave	May 4, '55	Grant's Cave	9.25
♀ ad.	June 5, '52	Devil's Head and Horns	May 4, '55	Roberts' Cave	27.00
♂ juv.	June 19, '54	Bat Cave	May 4, '55	Roberts' Cave	17.00

During the course of this study, only fourteen bats which had been banded in the maternity colonies were recovered at points away from these colonies (Table 4). The greatest observed distance that any had moved was 27 miles, and the mean distance was 10.6 miles. One of the juvenile females which was banded in Bat Cave on June 19, 1954, and was recovered nine miles away in Grant's Cave on July 31, 1954, subsequently returned to Bat Cave on November 14, 1954. A juvenile male which was banded in Bat Cave on June 19, 1954, and was recovered 4.5 miles to the southeast in Road Cave on November 14, 1954, was recovered again in Grant's Cave, 4.5 miles southeast of Road Cave, on May 4, 1955.

To test the homing abilities of *Myotis austroriparius*, 359 were captured in the maternity colony at Bat Cave, Alachua County, on the morning of May 7, 1954. These bats were banded and released that evening, in groups of about a hundred each, at distances varying from 18 to 178 miles from the home cave. The numbers of returns and recoveries from each of the release sites are summarized in Table 5. It seems significant that none returned to the vicinity of

TABLE 5. — *Returns and recoveries from a homing experiment on Myotis austroriparius captured in a maternity colony at Bat Cave*

RELEASE SITE	DISTANCE FROM SITE OF CAPTURE	NUMBER RELEASED	NUMBER RETURNED	NUMBER RECOVERED NEAR RELEASE SITE
Gainesville	18 mi.	80	18 (20%)	0
3 mi. NW of Mayo	45 mi.	100	8 (8%)	0
9 mi. S of Tallahassee	108 mi.	100	0	6 (6%)
3 mi. N of Marianna	178 mi.	79	0	6 (7%)

Bat Cave from distances exceeding 45 miles, and that none were recovered in the vicinity of the release sites at distances less than 108 miles. The distances traveled and the directions of movement of the 38 bats that were recaptured are shown on the accompanying map (Fig. 3).

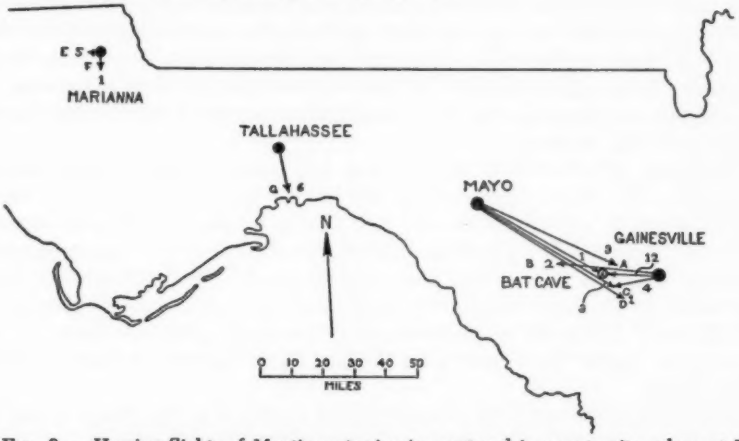

FIG. 3. — Homing flights of *Myotis austroriparius* captured in a maternity colony at Bat Cave. Lines indicate direction and distance traveled; numbers indicate number of bats. A, Leivonen Cave; B, Roberts' Cave; C, Road Cave; D, Grant's Cave; E, Old Indian Cave; F, Mud Cave; G, Boat house at St. Marks.

In another homing experiment, 25 bats were captured at a regular winter roosting site under the Waccasassa River bridge on State Highway No. 24 on March 21, 1955. They were banded and released at Gainesville, 31 miles to the northeast, the same evening. On April 17, 1955, very few bats, none banded, could be found under the bridge. On May 4, 1955, one of this group was recovered in the maternity colony at Grant's Cave, 8 miles west of the release point, and 27 miles northeast of the point of capture; and two more were recovered in another maternity colony at Roberts' Cave, 32 miles west of the release point, and 28 miles north of the point of capture. On October 18, 1955, two banded bats had returned to the bridge where they had been captured.

Limiting factors.—The following four factors have been suggested as limits on bat populations: (1) disease, (2) predation, (3) availability of food and water, and (4) number and size of roosting sites.

Disease is apparently unimportant for *Myotis austroriparius*. During the course of this study, which involved observations on over a million bats in every known cave colony in Florida, I have never found a dead bat, and have seen only one which appeared diseased. Two specimens out of several hundred examined by the Florida State Board of Health were found to have rabies, but rabies is apparently non-lethal in bats. Five bats were examined for nematode blood parasites, and about 100 for protozoan blood parasites, but no infestations were found.

Several species of ectoparasites are found on these bats, but their effects, if any, on the populations are unknown. Bat mites, *Spinturnix* sp. and *Ichoronyssus quadridentatus*, are abundant on the wing membranes of virtually every bat examined. Nycteribiid flies, *Basilia boardmani*, are common in the fur of the bats. Streblid flies, *Trichobius major*, are the most conspicuous parasites; the majority of bats are carrying from one to half a dozen of these flies. The one flea, *Sternopsylla texana*, collected from *Myotis austroriparius* by H. B. Sherman, is normally a parasite of *Tadarida brasilensis* and its occurrence on the *Myotis* was doubtless due to contamination from the *Tadarida* with which the *Myotis* was roosting.

Predation is believed to be the most important mortality factor among populations of *Myotis austroriparius* in Florida. Rat snakes, *Elaphe obsoleta quadrivittata* in peninsular Florida and *Elaphe o. spiloides* in west Florida, and corn snakes, *Elaphe guttata guttata*, are doubtless the most important predators on these bats. Both species are frequently found in bat caves, they are excellent climbers, and captive individuals will eat bats very readily.

Opossums, *Didelphis marsupialis pigra*, apparently prey on these bats in some of the caves. They climb after the bats on the highest and most inaccessible ledges.

I once found the wings of at least 42 bats scattered at the mouth of one of the maternity caves, where the bats had obviously been captured and eaten by an unidentified species of owl. I have never seen hawks attempt to capture *Myotis austroriparius* during the evening flights from the caves, as has been reported for other species of cave bats; the bats do not leave the caves until after sunset, when hawks are no longer active.

American cockroaches, *Periplaneta americana*, and the introduced Australian cockroaches, *Periplaneta australasiae*, are extremely abundant in all bat caves. They are chiefly scavengers, but frequently eat very young bats which have fallen to the floor before the latter can climb back to the clusters. Next to rat snakes, roaches are probably the most important predators on *Myotis austroriparius*.

Water is certainly not a limiting factor in Florida. Food may be when cool weather limits the supply of flying insects. Roosting sites cannot be a limiting factor, as only a small percentage of suitable caves are occupied; I have found these bats in only 25 of 154 known caves in Florida. Even the largest colonies contain fewer bats than can be accommodated. This situation exists in the upper Mississippi valley as well as in Florida. The size of the opening of the cave to the surface may be a factor in limiting colony size in certain caves.

SUMMARY

Myotis a. austroriparius occurs in the caverniferous karst regions of northern peninsular Florida and of western Florida, southwestern Georgia, and south-central Alabama.

In western Florida these bats hibernate in caves during the winter; in

peninsular Florida they are active during much of the winter, and usually roost outside caves. Most of the mating occurs in the autumn in western Florida, and in the spring in peninsular Florida. In the spring the pregnant females and some of the males gather into large maternity colonies in certain caves; these colonies contain from 2,000 to 90,000 adult bats; during this time, most of the males and the non-breeding females roost in other caves in western Florida, or outside caves in peninsular Florida. The young are born about the second week in May, and are on the wing by late June. In the autumn the bats desert the maternity colonies.

The habitat differences between the western Florida and the peninsular Florida populations are due largely to environmental temperatures and food supply. Summer temperatures in Florida caves are apparently ideal for optimum metabolic rates for the growth of the young. In western Florida, because of the lack of insect food and the frequency of freezes during the winter, these bats hibernate in caves. In peninsular Florida, flying insects are available during most of the winter, and freezes are rare, so that only short periods of dormancy are necessary; moreover, most of the caves are too warm to induce torpidity, so the majority of bats roost outside.

The population density of this species in north peninsular Florida is estimated at a minimum of 77 bats per square mile before the young are born, and up to 167 per square mile when the young are on the wing. In the adult population, the sex ratio is 43 per cent males in western Florida, and 39 per cent males in peninsular Florida. The sex ratio at birth is 51 per cent males. Sexual maturity is attained at the age of one year. Females bear a mean of 1.90 young per year. The majority of recaptures of banded bats were made at the cave in which they were banded; a few were recaptured in caves as far as 27 miles away. Homing experiments revealed that they could return from distances of up to 45 miles from the home cave. They are heavily infested with mites (*Spinturnix* sp. and *Ichoronyssus quadridentatus*) and parasitic flies (*Basilia boardmani* and *Trichobius major*). Their most important predators are rat snakes (*Elaphe obsoleta* and *E. guttata*), opossums (*Didelphis marsupialis*), and some species of owls. Cockroaches (*Periplaneta americana* and *P. australasiae*) prey on newborn young bats.

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EXPERIMENTAL STUDY OF FACTORS AFFECTING SEX RATIOS IN THE LITTLE BROWN BAT

BY ELIZABETH SMITH

In the course of investigations on the metabolism of the little brown bat, it became obvious that the numbers of males and females were far from equal in the populations studied. So many theories were proposed and so many questions were asked by owners of bat roosts and other interested persons that a series of experiments were performed to test some of the popular theories regarding sex ratios. This bat is useful for such studies because some of the most extreme sex ratios among mammals are found in bats (Mohr, 1952); each female produces only a single offspring per year; and fairly large numbers of animals may be collected at the same time from their roosts where they hang under the same environmental conditions (Smith, 1954).

This work was aided in part by a grant from Delta Kappa Gamma.

MATERIALS AND METHODS

Most of the little brown bats, *Myotis lucifugus lucifugus*, were collected from 12 roosts in attics and barns in northern Ohio and were examined within three hours of capture. Scattered single specimens were brought in by students. Over a period of seven years, 3,768 bats were examined.

Age of the adult bats was estimated by the amount of wear on the canine teeth. The youngest were those in which no wear was visible with a 10x hand lens (no wear); the next group had wear visible with the lens (slight wear); the oldest bats had wear visible with the naked eye (some wear). Each grouping probably represents several years. Blood was obtained by heart puncture. Hemoglobin determinations were done on a Spencer hemoglobinometer. The bats were weighed to the nearest tenth of a gram on a special

balance designed for these mammals; banding was done with No. 0 bands supplied by the U.S. Fish and Wildlife Service.

Sex is easy to determine by examination of the external genitalia. Each female produces a single mature ovarian follicle and a single offspring each year. Ovulation occurs in April; the young are born during June and July. The reproductive systems studied were fixed in Allen's B-15. Serial sections were cut at 4μ and stained with Mollier's quadruple stain (Conn and Darrow, 1943).

The primary sex ratio is the proportion between the sexes at the time of fertilization; the secondary sex ratio is that found at birth. Ratios observed at any time after birth are tertiary sex ratios. A "repeat" is a banded animal captured in the same place during the same season; a "return" is an animal captured in the same place during a subsequent season; a "recovery" is an animal recaptured at another locality. In each table P represents the probability that a difference as great or greater would be observed by chance alone. Weights and counts are given with their standard deviation.

RESULTS

No observations could be made on the primary sex ratio. The secondary sex ratio was 100:100, although the tertiary sex ratios varied widely with the age of the bats and the season of the year. The bats examined are listed by months in Table 1. Sex ratios for mature bats were always significantly different from a 100:100 ratio. Mature males were rarely collected. A tertiary sex ratio of 1:100 was obtained for all collections; the maximum ratio was 3:100 in June. For young bats the ratios were entirely different and, starting with a ratio of 100:100, decreased progressively from June through October. Males and females were born in equal numbers, but the number of males progressively decreased. The young males left the roosts and rarely returned.

TABLE 1.—*Monthly totals for bats captured in Ohio*

MONTH	MALES		FEMALES		SEX RATIO FOR JUVENILES	P[1] FOR JUVENILES
	ADULT	JUVENILE	ADULT	JUVENILE		
April	0	0	104	0		
May	6	0	385	0		
June	30	210	898	184	114 : 100	0.21
July	0	288	565	302	95 : 100	0.60
August	0	100	174	231	43 : 100	0.0001
September	3	43	76	144	30 : 100	0.0001
October	0	0	9	14	0 : 100	0.0002
December	0	0	2	0		
TOTAL	39	641	2213	875	73 : 100	0.0001

[1]P is the probability of a difference in sex distribution of the juveniles as large or larger than that observed, assuming that the true distribution is 100 : 100.

TABLE 2.—*Sex of bats according to date of birth*

WEEK BORN	MALES	FEMALES	RATIO	P[1]
2nd week in June	11	13	85 : 100	0.84
3rd week in June	48	35	137 : 100	0.18
4th week in June	41	42	98 : 100	1.00
1st week in July	8	7	114 : 100	1.00
2nd week in July	1	1	100 : 100	1.00

[1]P is probability of a sex distribution of the juveniles as great or greater than that observed, assuming that the true distribution is 100 : 100.

The secondary sex ratio was always 100:100. No significant difference in number was observed in all of the young bats collected during the time of parturition in June and July (Table 1). Bats less than a week old when captured were grouped by week of birth (Table 2) and again no significant deviation was observed. In addition, 28 bats (15 males and 13 females) were captured within a few hours of birth, as shown by the fact that the umbilical cord was not yet dry. The ratio is 115:100. The probability is 0.85 that this is a 100:100 ratio and that variations as great or greater would be obtained in random sampling.

Difficulties in pregnancy or parturition that might produce selective mortality have not been observed. Of the mature bats (all females) collected during the first two weeks in July, when pregnancy or lactation is unmistakable, 310 out of 314 animals (98.8 per cent) were either pregnant or suckling young. Each female bears a single young. No twins have been found. Apparently the females bear young at one year of age. The eight females recaptured the first season after they had been banded as juveniles were either pregnant or suckling. Eleven bats banded early in pregnancy were recaptured later and all were still bearing young in spite of the trauma involved in capture and banding.

TABLE 3.—*Sex of bats according to location of corpus luteum in the ovaries of the mothers*

OVARY	MALES	FEMALES	RATIO	P
Right	6	5	120 : 100	1.0
Left	4	5	80 : 100	1.0

The condition of the mother was considered in relation to the sex of the baby bats. The ovaries of the mothers of the first ten males and first ten females autopsied were examined in order to see in which ovary the single corpus luteum was located (Table 3). The ovary from which ovulation occurred did not affect the sex of the offspring. Erythrocyte counts were done on the same mothers. The mean and standard deviation for the mothers of males was $13.5 \pm 1.6 \times 10^6$ erythrocytes. The mean for the mothers of females was $14.3 \pm 1.2 \times 10^6$. The difference in means was $0.8 \pm 0.9 \times 10^6$. The probability that a difference as great or greater would occur on the basis of chance was 0.373. Similar

TABLE 4.—*Sex according to weights (in grams) of mothers at parturition*

MOTHER	MALE	MOTHER	FEMALE
5.8	1.9	6.6	2.1
6.7	2.1	6.7	2.0
6.7	2.1	6.9	1.8
6.9	2.2	7.1	2.4
7.0	2.3	7.3	2.2
7.1	2.2	7.4	1.8
7.2	2.0	7.4	2.3
7.2	2.1	7.6	2.0
7.3	2.2	8.0	2.0
7.3	2.0	8.0	2.3
7.4	2.0	8.1	2.3
7.4	2.3	8.2	2.3
7.6	2.2		
7.6	2.2		
7.8	1.9		
Mean: 7.1 ± .59	2.12 ± .13	7.4 ± .51	2.13 ± .19

Differences in means of mothers' weights = 0.31 ± .21, P = .139
Differences in means of babies' weights = 0.01 ± .14, P = .944

results were obtained with hemoglobin determinations. The mean for the mothers of males was 16.6±1.5 grams; the mean for the mothers of females was 17.3±1.5 grams. The difference in means was 0.7±0.7 grams and the probability that a difference as great or greater would be expected to occur by chance is 0.484.

Another factor considered was the weight of the mother at the time of parturition. The weights of the mothers and babies captured within a few hours of birth are listed in Table 4. No significant difference was found.

The age of the mother is considered in Table 5. These are bats captured within a week of birth in which each mother and offspring were placed in individual containers at capture so that there was no opportunity for a young bat to become separated from its mother. Since bats have but a single offspring each year this table also shows the chronological order of pregnancy. For neither age of mother nor chronological order of pregnancy was there a significant deviation in the secondary sex ratio.

TABLE 5.—*Sex of bats according to age of mothers*

WEAR ON TEETH OF MOTHERS	OFFSPRING		RATIO	P
	MALES	FEMALES		
None	9	8	112 : 100	1.0
Slight	18	23	78 : 100	0.53
Some	9	3	300 : 100	0.15

Although equal numbers of males and females were born, the number of males decreased steadily during the summer and autumn. Mature males were rarely collected. Of 3,768 bats examined, 39 (1.03 per cent) were mature males. They were found only in late spring and late summer on similar dates in different areas. Of the 39 males captured in seven years, 14 were obtained on June 7, 1951 at Berlin Reservoir, Wayland and Pricetown, but none were found at Burton.

Unequal sex ratios were also found in the banded bats. Although 20.1 per cent of the bats banded were males, only 6.1 per cent of the bats recaptured were males. Males comprise 9.1 per cent of the repeats (these were all young bats) but only 1.5 per cent of the returns. No male has been recaptured more than once, nor have there been any recoveries.

The tertiary sex ratio among the juvenile bats varies with the season of the year (Table 1). The young males apparently leave the roosts early and do not return. The decrease in number of males during the late summer is illustrated in Table 6 which lists the bats captured at one place—Wayland, Ohio—during one season. In the last two collections there was a significant difference in the number of males and females captured. Similar results were obtained in all of the roosts studied. Although fat storage begins in August and by the end of the month some females, both adult and juvenile, weigh as much as ten grams, only one juvenile male weighing over eight grams has been captured thus far. It was postulated that males leave the roosts before attaining that weight. However, the range in weights in juvenile bats is such that there is no significant difference in the mean weights of the juvenile males and juvenile females. For example on August 31 (Table 6), difference in means is 1.0±0.63 grams and the probability is 0.11 that a difference as great or greater would be obtained by chance. No males have been found after they leave the roosts.

Few social factors could be observed in the bat roosts. The bats hang on beams or in crevices and there is no attempt at making a nest. The roosting position in an attic or barn is changed at least once a day. The position of a bat in a group is apparently at random. Diagrams were made of the location of the bats in fourteen consecutive collections at the same roost and there was no duplication and no order or pattern could be observed even when the bats were not disturbed. No signs of social organization or

TABLE 6.—*Juvenile bats captured in Wayland, Ohio, during July and August*

DATE	NUMBER OF MALES	NUMBER OF FEMALES	MALES:FEMALES RATIO	MEAN WEIGHT MALES, GRAMS	MEAN WEIGHT FEMALES, GRAMS
7/13	27	23	117 : 100	5.2 ± 0.5	5.7 ± 0.7
7/26	16	24	66 : 100	5.5 ± .03	5.8 ± 0.7
8/4	7	12	58 : 100	7.0 ± 0.2	7.0 ± 0.5
8/15	2	3	66 : 100	5.8 ± 0.5	6.9 ± .02
8/22	3	14	21 : 100	7.5 ± 0.8	6.9 ± 0.7
8/31	2	10	20 : 100	6.7 ± 0.8	7.7 ± 0.8

pecking order could be found in the roosting arrangements or in the order in which the bats emerged to feed. On three consecutive evenings at one roost the first dozen bats were banded in the order of their emergence. No leader was found nor any order observed. All of the roosts observed were in large attics or barns in which the bats did not occupy a thousandth of the available space for hanging up. All were in localities in which mosquitoes and other insects were extremely abundant so that the food supply seemed ample. In the localities studied, the people became interested in their bats and there was no shooting or disturbance. No reason could be discovered as to why the young males left the roost and rarely returned.

DISCUSSION

Accurate data on sex ratios in mammals are difficult to obtain. Nothing is known of primary sex ratios. The sexes of the mammals studied are produced in almost equal number at birth (Parkes, 1926). In the case of man, the abundant data are of doubtful accuracy and difficult to analyze because of social factors such as wars, famines, abortions and prestige of sons (Lancaster, 1950). Data on wild mammals are scarce and are usually tertiary sex ratios which must be interpreted cautiously (Crew, 1952). Differences in the obviousness of the behavior and appearance between the sexes make any observations of doubtful value. For example, in rabbits, tertiary sex ratios of 120:100 are obtained by trapping or shooting the more active males whereas ratios of 84:100 are obtained by using ferrets (Elder and Sowls, 1942). Among the little brown bats the cave populations seem to be predominantly male, and summer roosts predominantly female (Cagle and Cochrum, 1943; Wimsatt, 1945; Mohr, 1952; Stegeman, 1954). Most investigators have been concerned only with various tertiary sex ratios. However, equal numbers of newborn males and females were found in Pennsylvania (Mohr, 1933), in Massachusetts (Griffin, 1940) and in Illinois (Cagle and Cochrum, 1943).

Numerous theories have been proposed to explain observed unequal sex ratios which are more extreme in bats than in any other known mammal (Mohr, 1952). Every stage in the process of reproduction has been considered critical in determining secondary sex ratios. Gametogenesis, insemination, and intrauterine development have been implicated. In addition, numerous environmental conditions and the "vigor" of the parents have been considered as the essential factors, but the exact stage at which the supposed effect occurs has not been specified.

The idea that the sex ratio is determined by the eggs alone has the weight of millenia behind it. Hippocrates (translated by Adams, 1886) states that the male fetus comes from the right ovary and the female from the left. In the bat, the ovary from which ovulation occurred is easily determined, since only one mature follicle and one corpus luteum is formed each year. Table 3 shows that the sex of the offspring was independent of the ovary from which ovulation occurred. Furthermore, all implantations occur in the right horn of the uterus.

Nutrition was supposed to produce dimorphism of eggs (Heape, 1907). Variations in the nutrition of the egg do not seem to apply to bats. Ovulation and fertilization take place in the very early spring at the end of the hibernation period during which all of the

bats have been living on stored fat. All bats should be affected in a similar manner. Equal numbers of males and females were born. The number of erythrocytes and the hemoglobin levels of the mothers made no difference in the sex of the offspring.

The maturity of the eggs at the time of fertilization has been considered important by many animal breeders. Pearl (1917) found no relationship between time of service and the sex of the offspring in cattle. In bats, if the length of pregnancy is fairly uniform, the bats born early in the season may be considered to have been fertilized early and those born late to have been fertilized late. Table 2 shows no difference in the sex ratios.

The vigor of the spermatozoa offers a fertile field for speculation in bats. Ovulation and fertilization occur in the spring about three months before parturition, but insemination occurs in the autumn, at intervals throughout the winter, and in the spring (Mohr, 1952; Wimsatt, 1945). Unfortunately, bats isolated in the autumn did not live until parturition. However, baby bats were grouped by week of birth (Table 2). Assuming that those born early in the season were fertilized early in the season, and vice versa, there is no significant difference in sex with season.

Selective uterine mortality is widely considered to be an important factor in altering secondary and tertiary sex ratios. Ciocco (1938, 1940) has summarized the evidence that the human male is less viable than the female at all ages. However, Tietze (1948) and McKeown and Lowe (1951) have excellent evidence that there is no significant difference during pregnancy in man. Nor was any evidence found in the little brown bat.

Various environmental factors supposed to influence the secondary sex ratio were carefully studied by Ciocco (1938). In thoroughly analyzing data from the Birth Registration Area in the U.S., he found that secondary sex ratios were not affected by urban or rural populations, by legitimacy of the child, by differences in the ages of parents, by season of the year or by climatic variations within continental U.S. However, he found a slight decrease in the ratio since 1930, a lower ratio in colored population than in white.

No social factors could be found in the roosts where the bats live in an extremely uniform environment without even making a nest. All of the bats feed at the same time. But the young males begin to leave the roosts in August and rarely return (Table 1), whereas the young females tend to remain at the roost and to return the next year. There is no significant difference in the sex of the offspring according to the age of the mothers (Table 5). Since bats have but a single offspring each year the chronological order of the birth is the same as the age of the mothers.

The "vigor" of the parents is somewhat difficult to measure objectively. For thirty specimens the oxygen consumption was measured. This depended on the stage of pregnancy and not on the sex of the embryo (Smith, 1955). Litter size cannot affect the ratio since only one ovarian follicle matures each year and only one offspring is born. Nothing is known of possible nutritional deficiencies in bats. But that such conditions should affect sex ratios as reported for mice (Parkes, 1926) is unlikely since pregnancy occurs at the same time in all females. The weights of the mothers at parturition may be another aspect of "vigor." The most vigorous mothers may capture the most insects. There was no significant difference in the weights of the mothers or of the babies (Table 4).

The location of the male bats is not known nor is it known why they leave the roosts. The occurrence of mature males in very small numbers, at various roosts at the same time and only in the late spring and late summer, suggested that the males might (1) migrate to some other area, (2) spend the summer in caves, (3) be scattered singly throughout a large area, or (4) have a higher mortality rate than females.

(1) Migration of males. Male *Myotis* may pass through Ohio in spring and fall migrations such as have been reported for *Lasiurus* (Allen, 1940). The collection of June 7, 1951, when mature males were found at three roosts suggests such a migration although no males were found at the fourth roost checked. When one male was found at St. Joseph and another at Berlin Reservoir on September 16, 1953, other localities were checked for a wave of migrating males. None were found at Burton, Pricetown or Deerfield. The other mature males were all captured on different dates. No dead *Myotis* were found near

lighthouses after storms as happened in the case of migrating *Lasiurus* (Allen, 1940). If males do migrate they certainly do not remain long at the roosts.

(2) Males remaining in caves during the summer. Griffin (1940) reported that males began hibernating in August in caves in Albany and Schoharie counties in New York. No caves are found in northeastern Ohio and none of the 389 young males banded in this area have been found in caves in other areas of Ohio or in Pennsylvania. The nearest caves investigated—the recently discovered cave at Harlandsburg, Pennsylvania and Dulaney's Cave near Uniontown, Pennsylvania—have small populations with a majority of males. Of the 1[illegible] males from those caves banded and released at roosts in northern Ohio, none have been recaptured in Ohio although 3 returns were obtained at Dulaney's Cave.

(3) Males scattered singly in northern Ohio. This possibility was suggested by observations in Iowa (Sherman, 1929) and in England (Deanesly and Warwick, 1939) where males were found scattered singly within ten miles of the roosts. This remains a strong possibility although no mature males have been found, since less than forty bats have been captured outside of roosts.

(4) Higher mortality rates in males than in females. In cave populations Mohr (1952) found a higher mortality rate in females than in males. But, in Ohio, the relative frequency of recaptured bats is much lower in males than in females. Only two males banded as juveniles have been recaptured in a subsequent season and both of those were in the roost where originally found. However, the data on males in this area are so inadequate that no conclusions can be drawn.

SUMMARY

Of 3,768 little brown bats, *Myotis lucifugus lucifugus*, obtained from roosts in northern Ohio, only 39 (1.03 per cent) were mature males. Equal numbers of males and females were born; the secondary sex ratio was not affected by the ovary from which ovulation occurred, difficulties in pregnancy, the number of erythrocytes or hemoglobin level of the mother's blood, time of fertilization or birth, chronological order of birth, or the weights or ages of the mothers. The tertiary sex ratios varied widely with the month of the year, since the juvenile males left the roosts and did not return.

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TWO NEW CENOZOIC MICROTINE RODENTS

BY CLAUDE W. HIBBARD

Further washing of matrix from the Saw Rock Canyon local fauna locality in southwestern Kansas has produced numerous parts of a vole previously reported as *Cosomys*. Sufficient material has been found to show that the vole is distinct from *Cosomys*. It is here reported as a new species of the Pliocene genus *Ogmodontomys*. A lower jaw of a small vole from the early Pleistocene Sand Draw local fauna of Nebraska is described as a new genus and species.

Ogmodontomys sawrockensis sp. nov.

(Figs. 1A-F, 2C-I)

Cosomys primus Wilson, Hibbard, 1949. Contrib. Mus. Paleo., Univ. Mich., vol. 7, no. 5, p. 103, fig. 2C-E.

Cosomys primus Wilson, Hibbard, 1953. Pap. Mich. Acad. Sci. Arts and Letters, vol. 38 (1952), p. 406.

Holotype.—No. 28166, University of Michigan Museum of Paleontology, part of the palatal region, which is broken just anterior to the posterior border of the incisive (anteropalatine) foramina and just posterior to the posterior palatine foramina. Only RM^1 is present. Collected in the summer of 1951, by the University of Michigan field party.

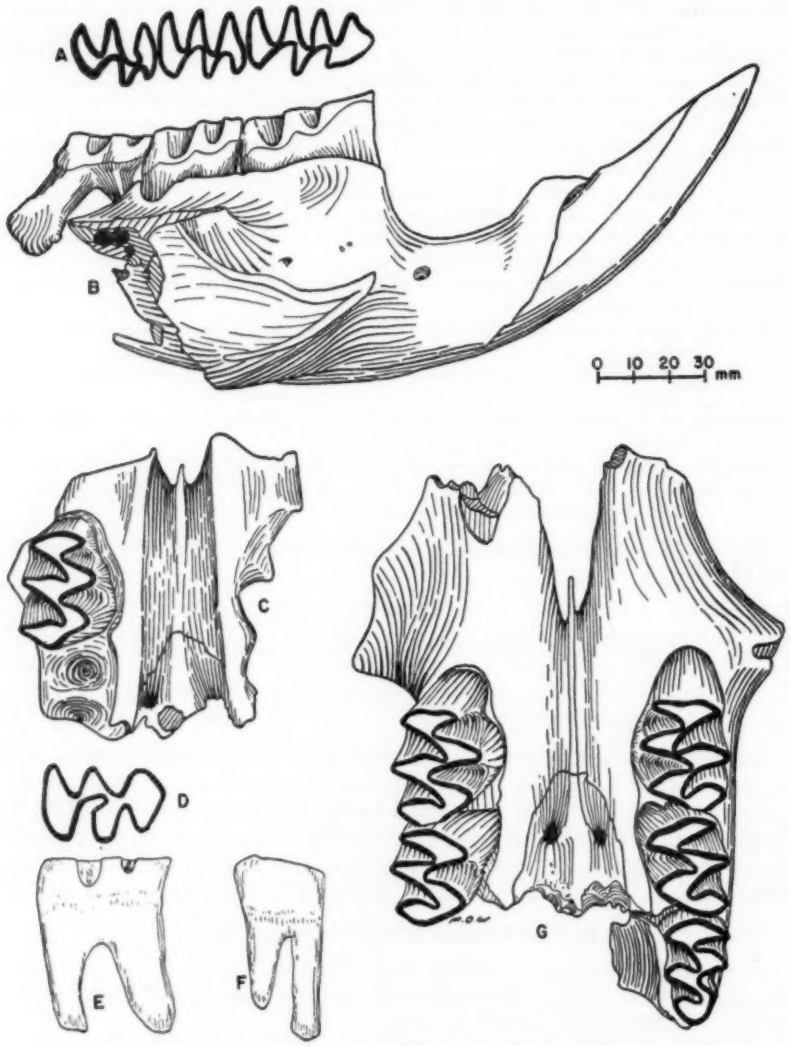


FIG. 1.– (A-F) *Ogmodontomys sawrockensis* sp. nov. (A and B) Occlusal view of RM_1-M_3, and lateral view of right ramus, paratype UMMP No. 29715. (C) Ventral view of palate with RM^1, holotype, UMMP No. 28166. All × 6. (D, E and F) Occlusal, lingual and anterior views of LM^3, No. 33654a. × 8. (G) Ventral view of palate with RM^1 and M^2, and LM^1-M^3, of *Ogmodontomys poaphagus*. × 6. Drawing by Michael O. Woodburne.

Paratypes.—No. 24344, is part of left lower jaw with M_1-M_2, and three isolated lower first molars; No. 29715, a fragmentary left lower jaw with incisor, M_1-M_3; No. 29716, parts of two right maxillaries, and a left maxillary with M^1 and M^2; No. 31013, part of a left lower jaw with M_1 and M_2 (Figs. 2C and D); No. 33653, numerous isolated upper and lower teeth; No. 33654, three left upper third molars and part of an upper incisor.

Horizon and type locality.—Lower Upper Pliocene, XI member of the Rexroad formation, Saw Rock Canyon, sec. 36, T. 34 S., R. 31 W., Seward County, Kansas.

Diagnosis.—Slightly smaller than *Ogmodontomys poaphagus* Hibbard with shorter crowned teeth. The lateral palatal grooves are distinctly deeper than those of *O. poaphagus.*

Description of holotype.—The lateral palatal grooves extend posteriorly from each of the incisive foramina to a point opposite the middle of M^2. The lateral palatal grooves are deep, especially in the anterior region of the palate, where they enter the incisive foramina (Fig. 1C). The maxillary forming the outer wall of each groove is vertical, not sloping upward and outward to the alveolar plane as in *Ogmodontomys poaphagus* (Fig. 1G). The shape of the outer walls of the lateral grooves is more like the condition observed in *Pliophenacomys primaevus* Hibbard, and the subgenus *Cosomys primus* Wilson from the Hagerman local fauna of Idaho. The maxillary part of the bony septum separating the incisive foramina is more pronounced and extends more ventrally than in either *C. primus* or *O. poaphagus.* The bony septum extends posteriorly as a distinct median ridge on the ventral side of the maxillaries and the anterior part of the palatine. This median ridge separates the posterior palatine foramina. These foramina are large. They are approximately twice as large as those of *C. primus.* The distance from the posterior edge of the right incisive foramen to the anterior edge of the right palatine foramen is 4.75 mm. The narrowest distance between the alveolar borders of the left and right M^2 is 2.5 mm. The anteroposterior length of M^1 is 2.65 mm. The right M^1 consists of an anterior loop and four alternating triangles.

Description of paratypes.—Numerous isolated teeth have been recovered. The upper molars have three well-developed roots. Each lower molar has two roots. The three-rooted condition of M^3 (Figs. 1E and F; 2F and G) distinguishes it from *Mimomys* (*Cosomys*) *primus* which has only two roots. Some of the first upper molars have the enamel at the base of the crown on the front of the tooth developed into a prominent shelf (Figs. 2H and I). The upper incisor has a shallow groove along the outer edge of the tooth.

The mental foramen is on the labial side of the lower jaw anterior to the root of M_1 and just anterior to the masseteric crest (Figs. 1B and 2D). There are parts of seven lower jaws with M_1 showing the position of the mental foramen. Its position is the same in all specimens regardless of stage of tooth wear. In *Ogmodontomys poaphagus* the mental foramen is more dorsally placed in some young and young adult specimens. The forward part of the ascending ramus leaves the jaw just opposite the last labial re-entrant angle of M_1. The

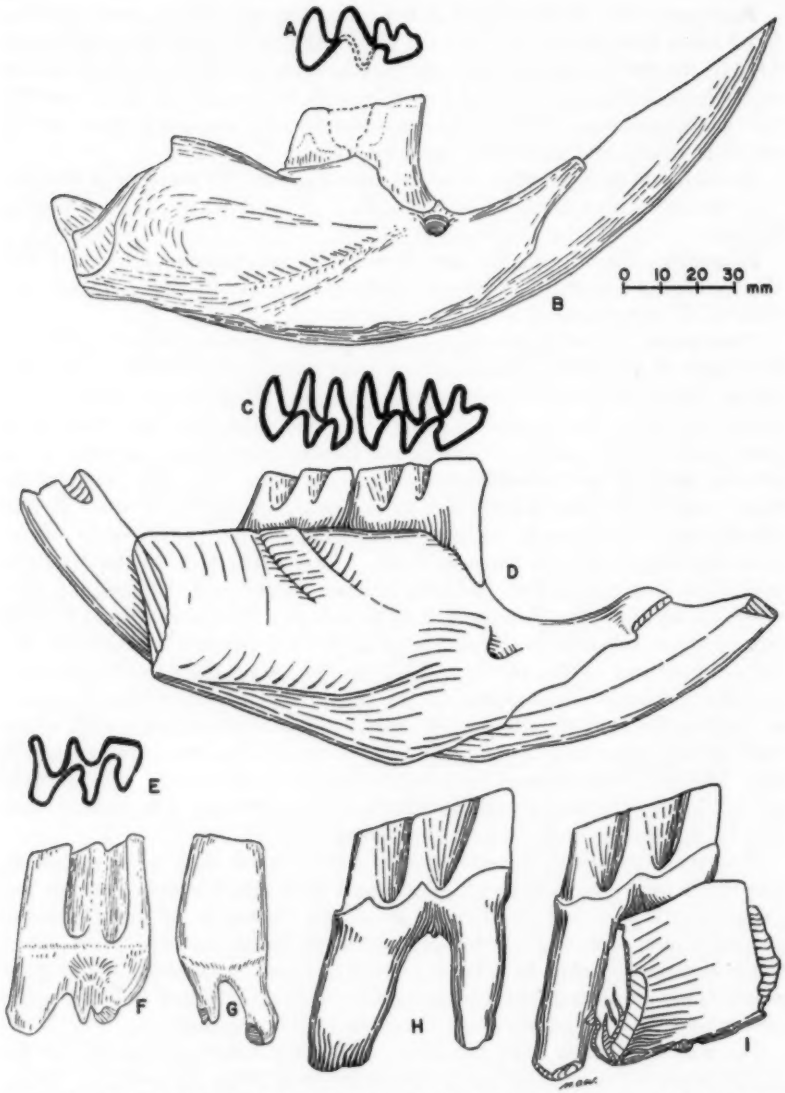


FIG. 2. – (A and B) Occlusal view of RM_1, and lateral view of right ramus of *Nebraskomys mcgrewi* gen. and sp. nov.; holotype UMMP No. 25610. × 8. (C-I) *Ogmodontomys sawrockensis* sp. nov. (C and D) Occlusal view of RM_1 and M_2 and lateral view of right ramus, UMMP No. 31013. × 6. (E, F and G) Occlusal, lingual and anterior views of LM^3, UMMP No. 33654b. × 8. (H and I) Labial views of RM^1, UMMP, No. 33653a-b. × 8. Drawing by Michael O. Woodburne.

anterior part of the lower jaw labial to the rest of M_1 is more slender than in *O. poaphagus.*

The reentrant angles of the upper and lower teeth are broad. The apex of the reentrant angles of the lower molars form, in most cases, a right angle to the longitudinal axis of the tooth. In *Mimomys* (*Cosomys*) *primus* the apex of the reentrant angle is directed forward and the enamel of the teeth is much thinner.

Specimen No. 29715 is the anterior part of a lower jaw (Figs. 1A and B) with incisor and M_1–M_3. The teeth are slightly narrower than those of O. *poaphagus.* The occlusal length of M_1–M_3 is 7.25 mm.

A complete palate of this form is needed to determine its true relationship to the other fossil microtines.

Nebraskomys gen. nov.

Genotype.—Nebraskomys mcgrewi, sp. nov.

Diagnosis.—Nebraskomys is a vole, with rooted teeth, smaller than *Pliophenacomys meadensis* Hibbard and *Pliolemmus antiquus* Hibbard. The mental foramen is located just anterior to the anterior root of M_1 and near the dorsal surface of the diastemal region. The incisor passes from the lingual side to the labial side of the jaw beneath the anterior root of M_2.

Nebraskomys mcgrewi sp. nov.
(Figs. 2A and B)

Holotype.—No. 25610, University of Michigan Museum of Paleontology, is part of a right lower jaw with incisor, M_1 and alveoli of M_2. Collected in the summer of 1948 by Claude W. Hibbard and party.

Horizon and type locality.—Lower Pleistocene, late Nebraskan, from bed no. 4 (sand and clay of McGrew, 1944, p. 34, Geol. Ser. Field Mus. Nat. Hist. vol. 9, no. 2) taken in association with *Geomys quinni* McGrew, from the Sand Draw local fauna, six miles north of Ainsworth, near the center of the W½ sec. 25, T. 31 N., R. 22 W., Brown County, Nebraska.

Description of holotype.—The lower jaw is that of an old adult. It is broken posterior to the alveoli of M_2. The incisor is smaller than that of *Pliophenacomys* or *Pliolemmus.* There appears to have been no pit between M_3 and the ascending ramus. The anterior part of the ascending ramus branches off opposite the posterior loop of M_1, which is more posterior than in *Ogmodontomys, Cosomys,* and *Pliophenacomys.*

The enamel of M_1 is thick and uniform. The posterior loop is closed off from the first alternating triangle. The first and second triangles are confluent, a condition which may be due to the stage of wear. The apex of the second triangle is missing. The second triangle is closed off from the third. The third triangle is confluent with the anterior loop. The anterior loop is the shape of that loop in *Ogmodontomys* and the subgenus *Cosomys.*

This species is named for Dr. Paul O. McGrew, who previously studied the Sand Draw local fauna.

Dscussion.—It is not known whether M_1 in immature and young adult speci-

mens contained three or five alternating triangles. It has not been possible to remove a quantity of matrix for washing, which without doubt would add many small forms to the Sand Draw fauna. A tooth of *Pliopotamys* (Hibbard, 1956, p. 167, fig. 5G, Pap. Mich. Acad. Sci. Arts and Letters, vol. 41), was recovered at this locality when we were washing matrix for mollusks (Taylor, 1954, p. 14, Pap. Mus. Zool. Univ. Mich. no. 557).

The late Nebraskan age assigned to the Sand Draw fauna applies to the invertebrates and vertebrates coming from below bed no. 3 of McGrew. The overlying sand and gravel may be of Kansan age.

Museum of Paleontology, University of Michigan. Received June 30, 1956.

IDENTIFICATION, ECOLOGY AND REPRODUCTION OF *MICROTUS* IN OHIO

By G. E. DeCoursey, Jr.

In 1941 Bole and Moulthrop described a new subspecies of the prairie vole, *Microtus ochrogaster ohioensis*. The range of this subspecies extends that of the prairie vole to central southern and southwestern Ohio. The meadow mouse, *Microtus pennsylvanicus*, is found in suitable habitat throughout Ohio. At the Wright-Patterson Air Force Base, eight miles northeast of Dayton, Greene County, Ohio, both *M. ochrogaster ohioensis* and *M. pennsylvanicus* occur in the same intermediate area.

An attempt was made to collect *Microtus* from this area and compare the ecology and reproduction of the two species. Between June of 1953 and July of 1954, 680 specimens of *Microtus* were collected. The measurements, weight, condition of the reproductive organs, and usually the habitat of each animal were recorded. The skull of each specimen was saved, and study or flat skins of 225 animals were preserved for future reference. Mice were collected by using standard snap back traps or rarely by hand. Peanut butter and oatmeal flakes were rarely used for bait; the majority of the traps were placed unbaited across runways or in burrows.

The author expresses his thanks to Dr. W. J. Hamilton, Jr. for his helpful suggestions during the course of this work and to both Dr. John T. Emlen and Dr. Hamilton for comments on the manuscript.

Identification

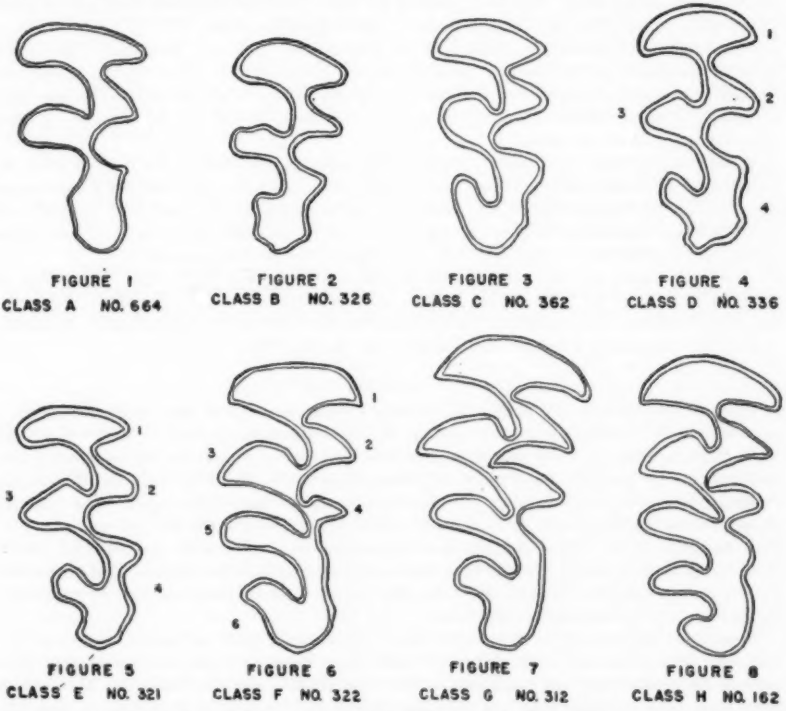
The feature that distinguishes *M. o. ohioensis* from the other subspecies of *Microtus ochrogaster* is the absence of any buffy color on the belly. This character is also the most obvious external difference between the other subspecies of the prairie vole and the meadow mouse. Hence, other less convenient characters must be used in order to distinguish the two species in Ohio.

The hypothesis that *M. pennsylvanicus* has six plantar tubercles and *M. ochrogaster* only five has been discussed and discarded by Bole and Moulthrop (1941) and Jameson (1947.) The former workers have pointed out that some *M. pennsylvanicus* have only five plantar tubercles. Hence this character indicates that an animal with six plantar tubercles is *M. pennsylvanicus*, but it reveals nothing about an individual with but five tubercles.

Bole and Moulthrop (1941) mention three characters to use in separating the two species. These are dentition, tail length, and texture of the pelage. In the present study dentition proved to be the most distinctive and reliable character, and was therefore adopted as the final criterion for identification. Those classed as *M. ochrogaster* were characterized by having four or five loops or triangles on the third molar of the upper jaw (Figs. 1-5). There was a great deal of variation in the shape and size of the fourth, or fourth and fifth loops or triangles, but a series of intermediate forms could be found between the extremes. The third molar of *M. pennsylvanicus*, in contrast, always displayed six or seven loops or triangles (Figs. 6-8).

Specimen 321 (class E) may appear to be intermediate between specimen 336 (class D) and specimen 322 (class F). Loop No. 4 of this specimen could be interpreted as three loops (Nos. 4, 5 and 6) as is done in the class F specimen. However, one skull intermediate in structure between those in classes D and E has been observed, while no skulls link the gap between classes E and F. Thus the biggest gap is between classes E and F and specimen 321 is considered as *M. ochrogaster*.

Some writers have credited *M. ochrogaster* with a consistently shorter tail than *M. pennsylvanicus*. Examination of the mice collected revealed that the tail lengths of the two species overlapped considerably. To illustrate this, the tail length of each male animal was plot-



FIGS. 1–8 — Enamel patterns of the third molars of the left upper jaws of *Microtus ochrogaster* (1–5) and *Microtus pennsylvanicus* (6–8). Of 647 skulls examined, 25 were of type A, 131 of type B, 144 of type C, 60 of type D, 3 of type E, 193 of type F, 90 of type G and 1 of type H.

ted against its total length. One would expect the tail of a meadow mouse to be shorter than that of a prairie vole whose total length is appreciably greater. But by comparing the tail lengths of all male animals whose total lengths are equal there should be two distinct groups if the tail length is a distinguishing feature. Examination of the graph revealed that 18 per cent of the male meadow mice had shorter tails then male prairie voles whose total lengths were equal or smaller. Repeating the above procedure on the data for female mice, one again finds an overlap of the tail lengths of the two species, this time of 16 per cent. Tail length in reference to weight or the length of the hind foot was then attempted, but an overlap of the tail lengths of at least 15 per cent of the population resulted in each case Jameson (1947), who studied populations of *M. ochrogaster* near Lawrence, Kansas, stated: "The shorter tail of *M. ochrogaster* will assist in establishing its identity where it occurs with *M. pennsylvanicus*." The word "assist" suggests that this character may not have been reliable in every case.

Bole and Moulthrop (1941) have stated that the fur of *M. ochrogaster ohioensis* is coarser than that of *M. pennsylvanicus*, but resembles it very closely in color. Examination of the dried skins has shown that the texture of the fur can serve as a satisfactory tool to separate the majority but not all of the specimens from the Dayton area. The coarser fur of *M. ochrogaster* could sometimes be detected on the facial area when it was not evident over the rest of the body. Flat skins were more often correctly identified than round skins, presumably because the facial area is more conspicuous in flat skins. The difficulty in recognition was greatest during the spring and summer months. Bole and Moulthrop (1941) list only 16 specimens on which they based their description of the pelage of the subspecies. Assuming that half of these were collected during the winter, when recognition on the basis of pelage is more reliable, the remaining eight specimens would not be expected to provide a great deal of variation.

A more conspicuous but very inconsistent difference is the color of the fur. In some *M. ochrogaster ohioensis* there is a "salt and pepper" stage with the light tan hairs contrasting sharply with the background of very dark gray hairs. Although this "salt and pepper" pelage was found more commonly in the winter, it occurred sparingly in the summer too. None of the *M. pennsylvanicus* examined had coats that exhibited this character.

After comparing the two species with reference to dentition, tail length, and pelage, it appeared that the only fully reliable method of identifying any single animal was by examining its dentition. The majority of individuals can be identified by their pelage or measurements, but one cannot place full confidence in these methods.

ECOLOGY

Lyon (1936), Hamilton (1943), and Findley (1954) have noted that where *M. pennsylvanicus* and *M. ochrogaster* occur together, *M. pennsylvanicus* appears to prefer the more moist habitat while *M. ochrogaster* predominates in the relatively dry areas. During this study mice were trapped in any place they were found to be common. This varied with the season, and specimens were taken from locations as far as three miles apart. The majority of specimens, however, were secured from a field approximately 250 by 350 yards in size. Two drainage ditches whose troughs were approximately six feet wide and eighteen inches deep ran through this area. While they were never seen to contain water, except within the twenty-four hour period following a rain, the soil at their bottoms was consistently more damp than that of the surrounding field.

More than 400 animals were taken in this area and their place of capture noted as in a drainage ditch or in the field. While it might have been desirable to operate trap lines periodically under standard conditions in both the ditches and the field, this plan would have required more time than was available. Since the intensity with which an area was trapped varied with the demonstrated abundance of the mice, a comparison of the numbers of one species caught in both habitats would be biased in favor of the area containing the higher mouse population.

Rather, one is forced to compare the relative numbers of each species from a single hab-

itat. This is done for each month in Table 1. The data lead to the conclusion that where *M. ochrogaster* and *M. pennsylvanicus* occur together, *M. pennsylvanicus* is more numerous in the moist situations while *M. ochrogaster* tends to predominate in the relatively dry areas.

ANNUAL MOVEMENTS AND POPULATION CHANGES

The annual movements of *Microtus pennsylvanicus* have received attention from Linduska (1950). He found that *M. pennsylvanicus* appeared in upland fields just prior to the first killing frosts in September and October. This invasion of the fields during the autumn, he stated, occurred each year the area was observed, and it was his belief that an autumn invasion of upland fields was a regular occurrence. But these populations, which reached a high level by December, had decreased to almost nothing by the following April.

A fall migration to a drier habitat, with a subsequent increase in numbers, similar to that noted by Linduska, was reflected in this study in the catches from the drainage ditches and field. The belief that the field population was extremely low during the July–October period is based on the absence of neat runways, burrows, cuttings or sign. The trap record reveals that seventy-five traps placed in the field from July 24 to July 30 did not catch a single specimen. Although the drainage ditches also gave very low returns at this time, they were relatively productive. One hundred and one traps in one of the ditches produced six specimens over a six-day period.

In contrast to these meager catches, large numbers of mice were easily taken during the winter months. Mouse burrows were prominent over several areas during February. Some of these areas had short grass only two to three inches long for cover, but trapping proved very fruitful. The relative ease of obtaining specimens is illustrated by trapping records for August and February. In August, 1080 trap-nights yielded 35 specimens; in February 420 trap-nights yielded 61 specimens.

The nature of this change in population is difficult to interpret because of two factors: (1) the practice of trapping the more productive habitat more heavily, (2) the predominance of *M. pennsylvanicus* in the summer catch and *M. ochrogaster* in the winter catch (Fig. 9). Due to these complicating factors, one may conclude very little except that (a) representatives of the genus *Microtus* were scarce during the summer months, but very common during the winter; (b) during the summer of 1953 voles were restricted to the drainage ditches and few marshy spots, and were mostly *M. pennsylvanicus*. During the winter of 1953-54 voles were abundant in the fields, were scarce about the drainage ditches and marshy spots, and were primarily *M. ochrogaster*.

The increase in numbers of *M. pennsylvanicus* caught during May and June might be explained by this species' reproductive activity. Figure 10 indicates that reproduction in *M. pennsylvanicus* was probably increasing during March, April and June of 1954. When the consecutive catches of *M. pennsylvanicus* are plotted (Fig. 9), this spring increase appears to be part of a repeated annual cycle, rather than a phase of a longer cycle.

The fall increase of *M. ochrogaster* is not so easily explained. Three possible explanations may be offered. (1) *M. ochrogaster* may have lived in the field during the summer, leading a completely fossorial life. Since any knowledge of the presence of the mice is based primarily on trapping and to a lesser extent on the presence on the surface of droppings, cuttings, runways or burrows, this possibility cannot be resolved. However, it seems unlikely. (2) The winter population may have resulted from the immigration of mice to the study area from a much larger area. The area in which the habitat studies were made and in which the great majority of the winter specimens were caught was surrounded by buildings, a parking lot, a highway, a railroad, a trailer camp and a golf course. It is thus difficult to surmise the origin of the immigrating mice. (3) The population may have increased by reproduction. *M. ochrogaster* rapidly increased in numbers during November, December and January (Fig. 9 and Table 1). But the incidence of mature females displaying embryos or placental scars was quite low during October, November and December (Fig. 10). Hence the fall increase of *M. ochrogaster* remains unexplained.

It appears that most of the prairie voles spent the summer months in the areas bordering

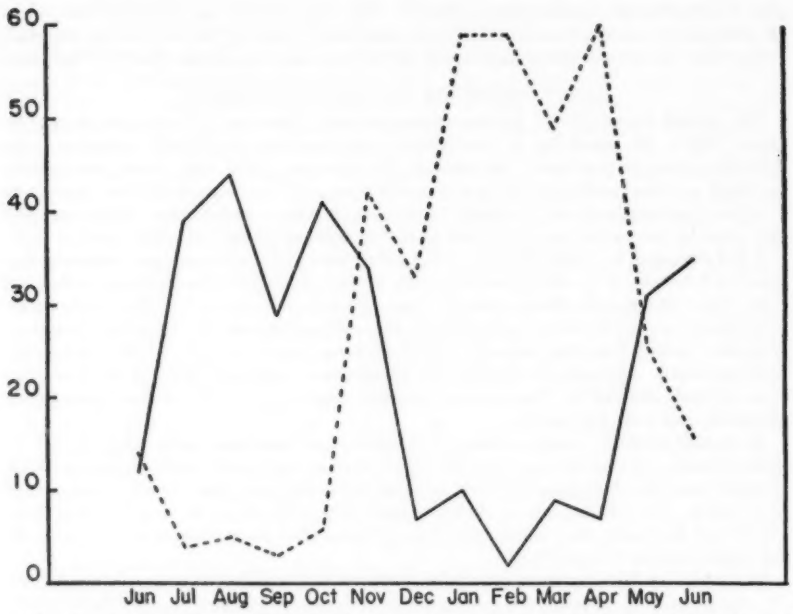


FIG. 9—A comparison of the numbers of *Microtus pennsylvanicus* (solid line) and *Microtus ochrogaster* (dotted line) caught during June, 1953, through June, 1954.

the *M. pennsylvanicus* population in the drainage ditches. It is possible that *M. ochrogaster* characteristically remains to a greater extent in the upland areas than was true in 1953 since this summer was a particularly dry one. The rainfall, as measured at the Dayton Municipal Airport ten miles away, for the June–October period was only 8.73 inches, 58 per cent of the normal amount for that period.

It is believed that the meadow mouse population moved up from the wetter area to winter in the upland field—the habitat dominated by the prairie vole. Such an hypothesis would at least partly explain the extreme change in numbers of each species which coincided with the change in habitat.

ASSOCIATES

During the trapping a few other small mammals were taken besides *Microtus*. *Peromyscus maniculatus bairdii* was taken commonly. Occasional *Peromyscus leucopus*, *Synaptomys cooperi*, *Blarina brevicauda*, and one *Cryptotis parva* were taken from traps placed across runways. *Citellus tridecemlineatus* and *Scalopus aquaticus* were both collected in the immediate area, but no *Microtus* were taken from the runways or tunnels of these mammals.

REPRODUCTION

The data reveals that, with one exception, all female *M. ochrogaster* having any discernible embryos or placental scars had a total length of more than 125 mm. This exception will be discussed later. Females were grouped for analysis of reproductive activity, and those that had a total length in excess of 125 mm. were termed mature; smaller individuals were considered immature. The mature were further divided into active (those whose uterine horns contained embryos, placental scars, or both) and inactive. Female *M. pennsylvanicus*

TABLE 1. — *A comparison of the numbers of Microtus pennsylvanicus and Microtus ochrogaster taken from the drainage ditches and field*[1]

MONTH	DRAINAGE DITCH			FIELD		
	Total Number	Per cent *penn.*	Per cent *ochr.*	Total Number	Per cent *penn.*	Per cent *ochr.*
June	7	57	43	4	25	75
July	19	95*	5*	0		
August	15	87*	13*	0		
September	17	88*	12*	0		
October	17	76*	24*	0		
November	30	60	40	13	0*	100*
December	0			40	18*	82*
January	2	100	0	34	3*	97*
February	0			57	4*	96*
March	3	33	67	22	5*	95*
April	0			58	9*	91*
May	7	86	14	30	47	53
June	23	96*	4*	27	48	52

[1] An asterisk indicates that the numbers of each species differ significantly from a 1:1 ratio at the 5 per cent level.

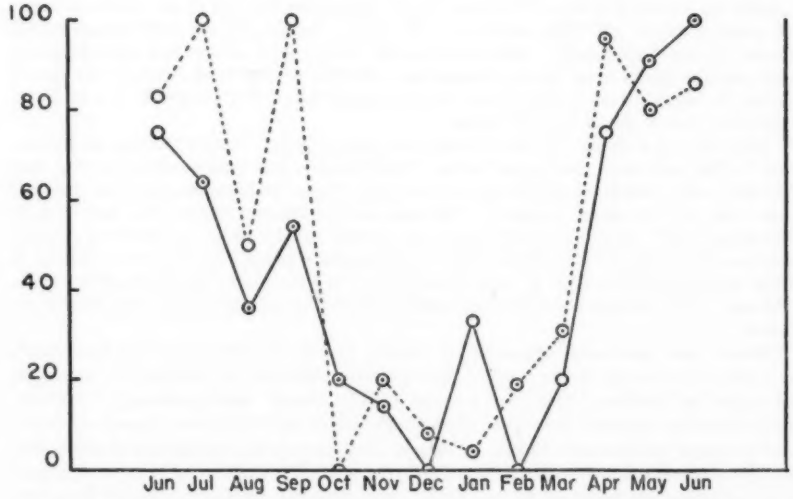


FIG. 10. — A comparison of the percentages of mature females that were sexually active of *Microtus pennsylvanicus* (solid line) and *Microtus ochrogaster* (dotted line). Those values which are shown as a circle surrounding a dot represent samples of 10 or more mice; those shown as a circle alone represent smaller samples.

were subdivided into mature active, mature inactive, and immature after a similar procedure.

In order to determine the breeding season, females were examined for embryos and placental scars. The results have been plotted (Fig. 10). The very small number of *M. pennsylvanicus* collected in the winter, and *M. ochrogaster* in the summer, prohibits any conclusions regarding the activity of either species during the entire year.

Some female *M. ochrogaster* were found pregnant or with placental scars during every month except October (Fig. 10). The next lowest percentage occurred in January, when only one out of twenty-eight or 4 per cent of the mature females had placental scars or embryos. In this single specimen the placental scars were not fresh, and since the animal was taken on January 12, the actual birth of the young probably occurred very early in the month if not in December. Thereafter, the percentage of mature females that were active continued to climb steadily until May when it decreased slightly. Jameson (1947) did not find any breeding females in Kansas during September, December or January, but he does not state how many specimens were examined. Fisher (1945) found the prairie vole breeding in Missouri in November, December and January. It seems likely that the breeding season of this species varies as Hamilton (1941) has found with the meadow mouse.

Breeding in *M. pennsylvanicus* declined from 64 per cent of the mature females in July to 0 per cent in December and February. The absence of any apparent reproduction could have been the result of any one or a combination of four causes. (1) It could result from the very small number of mature females examined. Only four mature females were inspected during December, and one during February. (2) It may be that there were so few *M. pennsylvanicus* at that time that a female passes through her estrous period without finding a fecund male with whom to mate. Hamilton (1941) stated that one of the requirements for breeding throughout the winter in *Microtus pennsylvanicus* appears to be a high density, so that a female will be likely to meet a fertile male during her short estrous period; hence the association of breeding throughout the year with high density. This would explain the taking of young of the common *M. ochrogaster* but not of the relatively scarce *M. pennsylvanicus*. (3) It is possible that the mature females did not pass through estrous periods during those months. Baker and Ransom (1932) were able to halt reproduction in *Microtus agrestis* by lowering the temperature sufficiently. This cold affected only the females; the males remained fertile even when no young were being produced. (4) It is possible that none of the males were fertile.

Male mice of both species were divided into mature active, mature inactive, and immature for the analysis of their reproduction. Prairie voles whose total lengths were less than 125 mm. were considered immature; meadow mice whose total lengths were less than 138 mm. were also considered immature. This basis of classification differs from that used by Hamilton (1937) who found that weight was a better tool by which to divide *M. pennsylvanicus* into mature and immature. But when weight was used on the data collected in Ohio, a considerable amount of overlap occurred during the height of the breeding season. Although some overlap occurred when total length was employed, it was considerably reduced.

Mature male specimens collected from January to June of 1954 were considered fertile or active if the tubules of the cauda epididymis were visible to the unaided eye, a method advocated by Hamilton (1941) and Jameson (1947). Mature male specimens of *Microtus pennsylvanicus* collected from June through December of 1953 were considered active if the seminal vesicles were 10 mm. or longer. Mature male *M. ochrogaster* obtained during the same period were considered active if the seminal vesicles were 11 mm. or longer. This evaluation was based on the subsequent examination of specimens collected from January to June of 1954 when the size of the tubules of the cauda epididymis was recorded as well as the size and position of the testes and seminal vesicles. Of 58 *M. pennsylvanicus*, active males had testes and seminal vesicle lengths of 8-14 mm. and 10-27 mm. respectively, while inactive mature males had testes and seminal vesicle lengths of 4-10 mm. and 3-9 mm.

respectively. Of 131 *M. ochrogaster*, active males had testes and seminal vesicle lengths of 6-10 mm. and 10-27 mm. respectively, while inactive mature males had testes and seminal vesicle lengths of 6-10 mm. There is a rough correlation between the visibility of the tubules of the cauda epididymis and the size of the seminal vesicles. The fact that this correlation appears to be true for *M. pennsylvanicus* and not quite so for *M. ochrogaster* can probably be explained by noting that during this period more than twice as many *M. ochrogaster* were examined as *M. pennsylvanicus*. The monthly per cent of mature males of each species that were fertile is plotted (Fig. 11). Some of the samples of each species are so small that no detailed comparison is justified.

The zero per cent of *M. ochrogaster* for October is probably deceptive since only four mature specimens were examined. However, eighteen such males were examined during December; yet none were fertile. It is notable that pregnant females were found in every month except January. Consequently, the dearth of reproduction in *M. ochrogaster* in December may have been the result of the lack of fertile males rather than an anestrous condition of the females. This contrasts with Jameson's findings which indicated that the breeding season in *M. ochrogaster* was limited by the females, not the males. Hamilton (1941), working with *M. pennsylvanicus*, reached the same conclusion as Jameson.

The number of embryos or fresh placental scars served as a source of information concerning the number of young per litter of each species. There is no significant difference between the number of embryos and placental scars of the left and right uterine horns of either species. Thirty-five *M. pennsylvanicus* litters average 4.48 (1-8) young per litter; thirty-five *M. ochrogaster* litters average 3.40 (1-5) young per litter. This difference is significant at the 1 per cent level, and agrees with the separate findings of Hamilton (1941, 1943) and Jameson (1947), who have remarked on the smaller litter size of *M. ochrogaster*. Both have noted that females of *M. ochrogaster* have only six teats, while those of *M. pennsylvanicus* have eight. Jameson further states that usually a lactating prairie vole shows evidence of only the four abdominal teats being nursed.

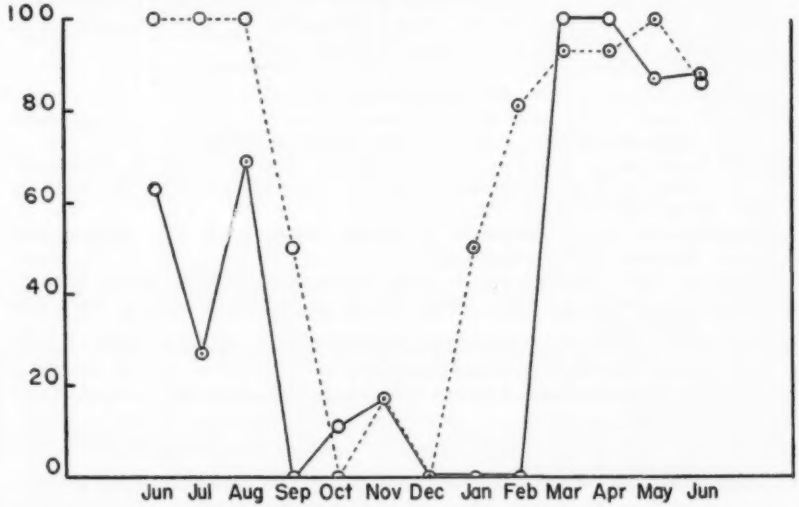


FIG. 11.—A comparison of the percentages of mature males that were sexually active of *Microtus pennsylvanicus* (solid line) and *Microtus ochrogaster* (dotted line). Those values which are shown as a circle surrounding a dot represent samples of 10 or more mice; those shown as a circle alone represent smaller samples.

An apparent example of early sexual activity was observed in specimen 645. This female *M. ochrogaster* contained one 3 mm. embryo in each uterine horn. The measurements for this specimen were: total length, 114 mm.; tail, 31 mm.; hind foot, 16 mm.; and weight, 13 grams. While the age of this specimen cannot be determined with any exactness, it was estimated at fifteen or sixteen days on the basis of the growth curve of the meadow mouse as determined by Hamilton (1937). The lowest weight and total length of any other female *M. ochrogaster* containing embryos or placental scars were 20.5 grams and 126 mm. respectively. Gravid females weighing 25-30 grams were taken commonly. Since four other *M. ochrogaster* females, weighing between 13 and 17 grams, were caught during the same month, and none of these had embryos or placental scars, it seems probable that the early sexual activity of specimen 645 is an exceptional case.

SUMMARY

Three hundred and seventy-seven *Microtus ochrogaster* and 303 *Microtus pennsylvanicus* were collected at Wright-Patterson Air Force Base, Greene County, Ohio, between May, 1953 and July, 1954.

Dentition was the only consistently satisfactory feature found for distinguishing *Microtus pennsylvanicus* from *Microtus ochrogaster ohioensis*. Identification of most specimens was possible by means of the pelage and measurements, but this method was not infallible.

The *Microtus* population was relatively scarce during the summer of 1953 and the early summer of 1954. During this time the population was concentrated in the drainage ditches and marshy spots and was made up mostly of *M. pennsylvanicus*. During the winter of 1953–54 a large population of *Microtus*, composed chiefly of *M. ochrogaster*, was present in the field.

The average litter size of *M. pennsylvanicus* was 4.48; that of *M. ochrogaster* was 3.40. There is some evidence that reproduction in *M. ochrogaster* is at least sometimes limited by the absence of fertile males.

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THE POPULATION AND DISTRIBUTION OF TWO SPECIES OF *PEROMYSCUS* ON SOME ILLINOIS STRIP-MINED LAND

By B. J. Verts

An evaluation of the wildlife and recreational potential of strip-mined land included a mammal survey. The initial investigation between August 4, 1954 and September 29, 1954 was made to inventory the population of mammals. In the course of the study a correlation between the distribution of two species of *Peromyscus* and the age of the stripped areas was evident. A second and more intensive investigation conducted from January 17, 1955 to May 5, 1955 furnished additional data to substantiate this correlation.

Description of the Area.—The area studied, comprising about 1,829 acres, is located in Perry County about seven miles south of Pinckneyville and one mile west of Pyatt. Strip-mining operations were begun on this land in 1932 and continued until 1950 (except 1934) resulting in 18 mined areas, each of different age and varying in size and shape. To remove the coal, the soil and rock (overburden) is "stripped off" and piled to one side. The operation is repeated with the subsequent overburden piled where the coal was previously mined. The resulting topography is one of alternate, parallel ridges and valleys which vary in direction, height, slope and shape within the different aged tracts. Spoil piles, on the average, are between 20 and 30 feet in height, 50 feet from crest to crest, and have a 45° slope.

The exposed materials consist of rock, shale and subsoil as the topsoil is buried deeply during the mining. The surface soils are almost devoid of organic matter, but generally are rich in phosphates and potassium (Brewer and Triner, 1956). Considerable erosion has occurred, especially in the older stripped areas where spoils are more rounded and valleys contain more alluvial materials.

Vegetation of the Area.—In general, the vegetation of the strip-mined lands is composed of blackberries and dewberries, *Rubus* spp., goldenrod, *Solidago* spp., sumac, *Rhus* spp., frost-weed aster, *Aster pilosus*, broomsedge, *Andropogon virginicus*, and white sweet clover, *Melilotis alba*, interspersed with widely spaced trees. An abundance of cheat, *Bromus secalinus*, is found on many unshaded south and east slopes. Cottonwood, *Populus deltoides*, sycamore, *Platinus occidentalis*, and sandbar willow, *Salix interior*, are the predominant trees. (Plant taxonomy is according to Jones, 1950). In strippings of all ages localized areas are completely devoid of vegetation.

The trees in the more recent strippings average about two inches in diameter at breast height and increase in proportion to the age of the stripped area until in the 1932 strippings cottonwood trees as large as 24 inches d.b.h. may be found. Then density of trees, however, is relatively uniform throughout the different aged strips (Brewer and Triner, 1956).

Plantings of shortleaf pine, *Pinus echinata*, and jack pine, *Pinus banksiana*, and deciduous plantings consisting of osage-orange, *Maclura pomifera*, black locust, *Robina pseudo-acacia*, and catalpa, *Catalpa speciosa*, are located in

several of the different aged areas. Most pine plantations contain an herbaceous understory, but one planted in the 1939 stripping has closely spaced trees and little herbaceous vegetation.

Materials and Methods.—Museum special and ordinary mouse traps were set in lines consisting of from 30 to 50 stations each, with the stations spaced at 10-yard intervals. Two traps were set at each station within a three-foot radius of the station marker; however, the stations or traps were not necessarily placed in the most favorable habitat, but were set at random. The traps were baited with a mixture of peanut butter, oatmeal, and DDT (one tablespoon of 50 per cent wettable powder per pint of bait, to discourage bait-pilfering insects). Trap-lines were operated for two consecutive nights and examined the following mornings on all 18 different aged areas in both summer-autumn and winter-spring periods. Winter-spring trap-lines were placed in different locations than those of summer-autumn, in order to sample a larger area. The lines were arranged so that approximately equal numbers of traps were on crests, in valleys and on slopes of the spoils. The number of trap-nights in the different aged strips varied from 284 to 412 with a mean of 345.

To determine vegetative characteristics of the different aged strips, eight to ten meter-square quadrats were established along each trap-line site, 50 yards between each quadrat. A total of 341 quadrats were established on the study area. The plant species, number of stems of each, the average height of the vegetation, and percentage of bare ground were recorded for each quadrat. A comparison of the vegetation of each aged stripping showed no significant differences in species composition, relative abundance, height, or percentage of bare ground. The only measurable difference in the vegetation between the earliest and the most recent strippings was the increase in tree diameter and height.

Results.—A total of 2,724 trap-nights in the summer-autumn period yielded 67 *Peromyscus maniculatus bairdii* (Hoy and Kennicott) and 131 *Peromyscus leucopus* ssp. The *Peromyscus leucopus* found in this area is probably an intergrade between *Peromyscus leucopus noveboracensis* (Fischer) to the north and *Peromyscus leucopus leucopus* (Rafinesque) to the south (Cory, 1912; Hamilton, 1943). In the winter-spring period 3,479 trap-nights produced 360 *P. m. bairdii* and 185 *P. leucopus.*

P. m. bairdii probably had a higher population in the winter-spring than in summer-autumn as .1029 and .0246 specimens per trap-night were taken in the two periods, respectively. In winter-spring, 79 per cent (277) of this species were juvenile animals, but only 23 per cent (14) were in this class in summer-autumn. The predominance of juveniles in the winter-spring period would tend to indicate that this form breeds throughout winter at this latitude. In a study in Michigan, Burt (1948) found that representatives of this subspecies bred occasionally throughout winter.

These data indicate that the population of *P. leucopus* did not vary greatly in the two trapping periods as .0481 specimens per trap-night were taken in summer-autumn and .0529 specimens per trap-night in winter-spring. The

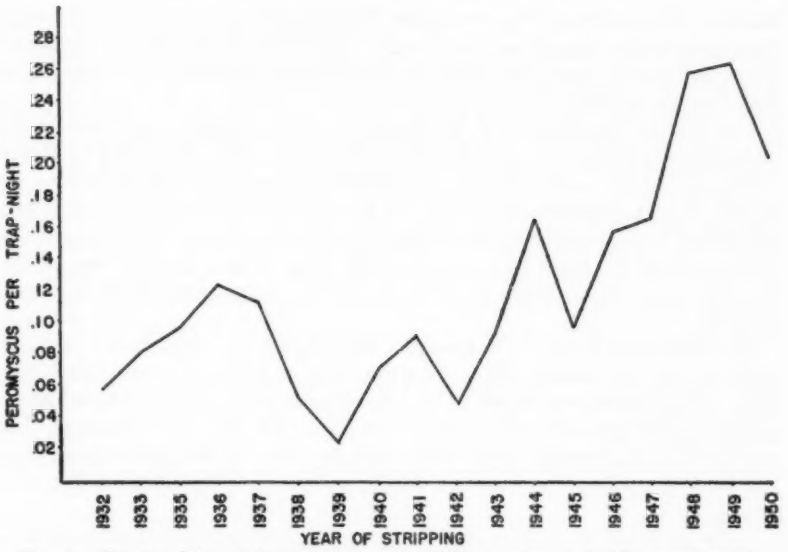

FIG. 1.—The populaton of *Peromyscus* on some Illinois strip-minded land, 1954-1955.

juvenile-adult ratio was approximately the same in both periods with 83 per cent adults in summer-autumn and 86 per cent adults in winter-spring.

In the population of *P. leucopus,* the juvenile sex ratio was significantly different from that of the adults and this difference was constant in both trapping periods. The juvenile and adult populations consisted of 70 per cent and 40 per cent females, respectively. Perhaps females have a greater mortality rate than males or the adult males, having a larger home range (Stickel, 1946), come in contact with traps more often. The sex ratio of juvenile and adult *P. m. bairdii* was nearly equal at both trapping periods; 44 per cent of the juveniles were females and 39 per cent of the adults were females.

The total number of mice in the population varied greatly between the different aged strips but tended to be of greatest density in more recently stripped areas (Fig. 1). The 1949 strippings produced .263 mice per trap-night whereas the 1936 strip yielded only .123. In general, the intermediate aged strips, containing both species of mice in more or less equal numbers, had a smaller population than either earlier or later strippings (Fig. 1). This possibly indicates that areas of intermediate age lack ideal habitat for either species and the existing mouse populations in these strips are forced into the poorer habitat as a result of the higher populations in both the earlier and later stripped areas. Intermediate aged spoils, however, may contain habitat suitable for both species with interspecific competition holding the population at a lower level. Conversely, Dice (1922) observed that antagonism between these two species was not an important factor in their selection of habitat.

The mouse population in the dense pine plantation in the 1939 stripping was

smaller (.022 specimens per trap-night) than in pine plantings where the trees were more widely spaced and herbaceous vegetation abundant. The *Peromyscus* population in open pine and mixed hardwood plantations was similar to that of other habitats.

The prairie deer mouse, *P. m. bairdii*, usually exhibits a preference for prairies, open fields and sand beaches (Hamilton, 1943; Burt, 1948). Harris (1952) found that in laboratory experiments with artificial habitats this subspecies prefers grasslands to forests. In the stripland study, *P. m. bairdii* predominated in the more recently stripped areas and comprised 98.8 per cent (69 specimens) of the mice taken in the 1950 strip. With increased age of the stripped areas, the percentage of *P. m. bairdii* in the population decreased (Fig. 2).

The white-footed mouse, *P. leucopus*, has a habitat preference of wood and brush lands, but occasionally will range into more open areas (Hamilton, 1943). This species was found to be predominant in the earlier stripped areas, making up 100 per cent of the catch in the 1932, 1933 and 1935 strippings. The percentage of *P. leucopus* in the total catch decreased in the more recent strips and made up only 1.2 per cent (a single specimen) of the catch in the 1950 strip (Fig. 2).

So far as could be determined, there was no microecological separation of the two species in areas where both occurred. Occasionally both species were caught at the same station on the same night or both were taken at the same

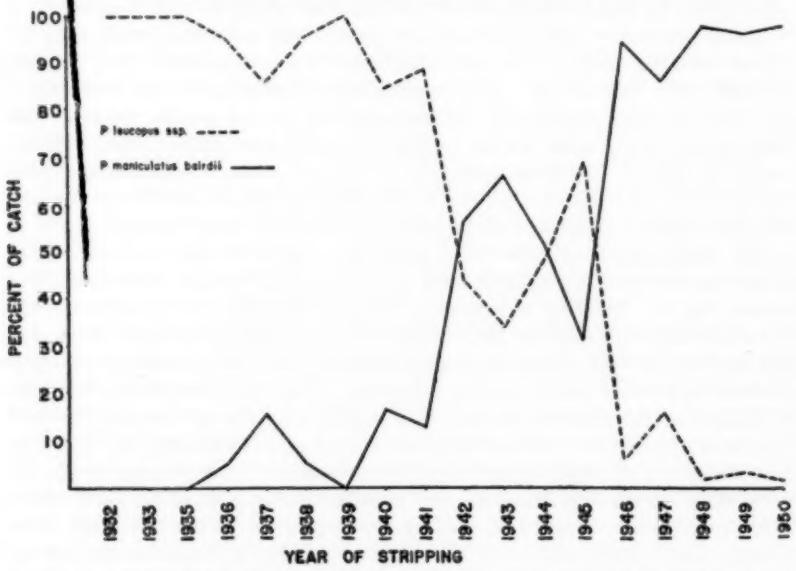

FIG. 2. — The distribution of two species of *Peromyscus* in the various aged strips on some Illinois strip-mined land, 1954-1955.

trap location on successive nights.

Conclusions.—As no measurable differences in the plant composition between the earliest and latest strippings could be found, the distribution of the two species of *Peromyscus* does not seem a result of plant succession. The percentage of bare ground, annuals, grasses, woody vegetation, perennials and biennials, and the average stems per square meter show no correlation with the distribution of these mice (Fig. 3). The rate of secondary plant succession is usually dependent on the amount of soil disturbance and the amount of vegetation remaining on the land (Braun, 1950). Strip-mining causes a complete reversal of the soil profile and an elimination of all plants; therefore, the 19 years separating the oldest from the most recent strippings perhaps is not a sufficient amount of time for recognizable differences in plant composition to develop.

Even though no plant succession can be demonstrated, the vegetation may control the distribution of the mice. The techniques commonly used to measure vegetation may not be sufficiently refined to record important minute differences. Other factors which might be considered are light, water, food, accumulated litter, temperature and relative humidity. In California, *P. maniculatus* was found to be at a disadvantage in areas where accumulations of duff were present (Andrewartha and Birch, 1954). Dice (1922) found in laboratory experiments with *P. m. bairdii* and *P. l. noveboracensis* that water, food, temperature and relative humidity did not limit the animals to their respective habitats. Dice (1931) also stated that the distribution of these forms is influenced by a reaction of the mice to the visual and other stimuli associated with forests and prairies. Light intensity possibly plays a role in the distribution of the *Peromyscus* on this strip-mined area, as the increase in size of the trees in the progressively older stripped areas would tend to decrease the amount of light in the mouse habitat. To measure any of these factors accurately on strip-mined land would be extremely difficult. Within a given aged stripping, for example, the area stripped in 1932, north, south, southeast and northwest facing slopes are present. In the same stripping, the ground cover varies from bare soil and rock to areas with extremely dense vegetation several feet in height; also, heavy shade prevails in some spots, no shade in others. These great differences within a single aged area make the measurement of climatic and edaphic factors beyond the scope of this study.

It is probable that no single factor is responsible for the distribution of the *Peromyscus* on this strip-mined land. Rather, the distribution reflects the total effects of all the variables and their interactions.

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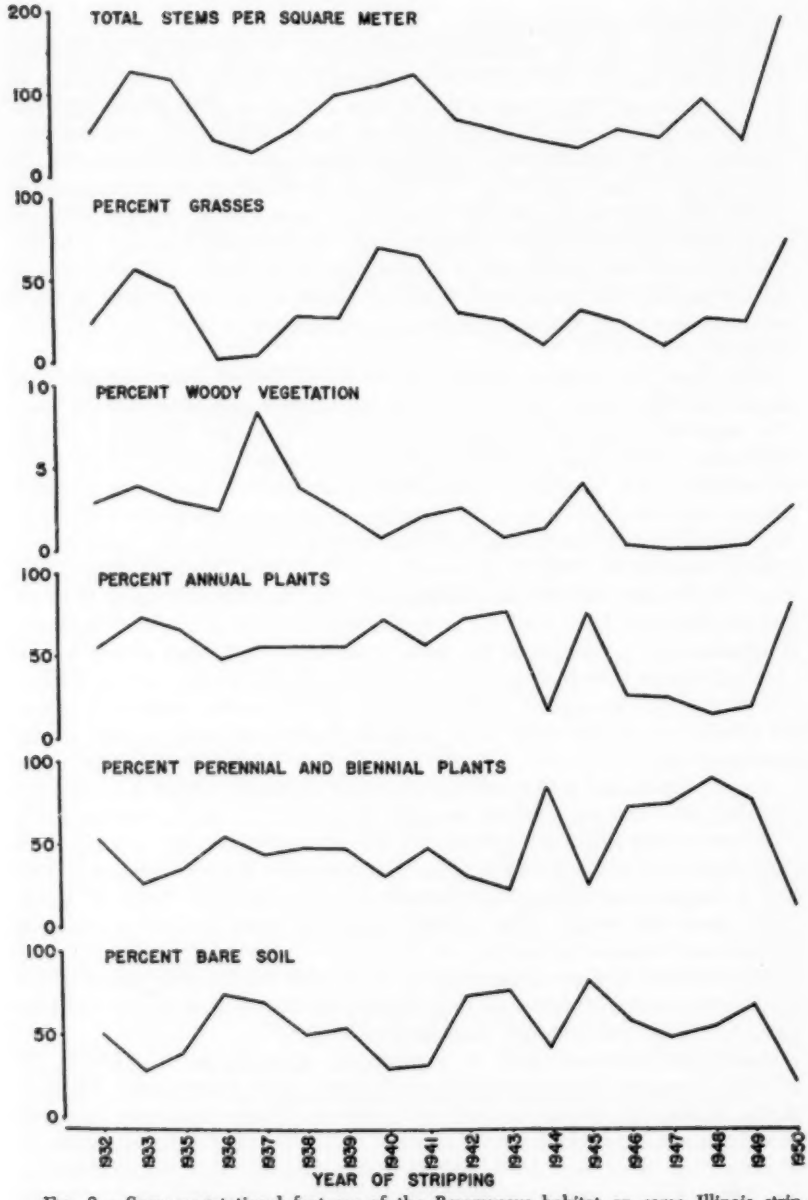

FIG. 3. — Some vegetational features of the *Peromyscus* habitat on some Illinois strip-mined land, 1954-1955.

study area.

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Summary.—Two periods of trapping on strip-mined land in Southern Illinois showed that *P. m. bairdii* had a higher population in the winter-spring period than in the summer-autumn period. A large proportion of the specimens taken in winter-spring were juveniles, but only a small percentage taken in summer-autumn were juveniles. The size of the catch indicated that populations of *P. leucopus* were approximately the same size at both trapping periods; also the percentage in each age class was similar. The ratio of females to males of this species was greater in the juvenile population than in the adult population.

The number of *Peromyscus* caught varied greatly between the different aged strips, but the animals tended to be more abundant in both the oldest and most recent stripped areas and less abundant in intermediate aged areas.

P. m. bairdii was the predominate form in the most recent strippings, but decreased in dominance with the increased age of the spoils. The percentage of *P. leucopus* in the total catch increased with the age of the strippings and became the only species of *Peromyscus* taken in areas mined previous to 1936.

Plant composition seemingly was not a factor in the distribution of these mice, as no measurable differences were found in species composition between the earliest and latest strippings.

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TEMPERATURE REGULATION, HIBERNATION, AND AESTIVATION IN THE LITTLE POCKET MOUSE, *PEROGNATHUS LONGIMEMBRIS*

By George A. Bartholomew and Tom J. Cade

The little pocket mouse, *Perognathus longimembris*, was selected for a study of temperature regulation because (1) it is one of the smallest North American rodents (adult weight, 6.5 to 10 grams); (2) it is a member of the highly specialized family Heteromyidae; (3) it is locally very abundant; (4) it is readily maintained in captivity; and (5) nothing was previously known about its temperature regulation.

Despite the abundance of pocket mice, very little has been published on the physiology of any member of the genus *Perognathus*. Hall (1946) adduced circumstantial evidence for the occurrence of hibernation in some species of pocket mice and its absence in others. Scheffer (1938) found that *Perognathus parvus* showed an irregular dormancy during the winter but he determined no body temperatures. We are unaware of any other published information concerning temperature regulation in the genus.

MATERIALS AND METHODS

P. longimembris occurs commonly in eastern and southern California, extreme northwestern Mexico, and throughout much of the Great Basin, reaching the northern limit of its distribution in southeastern Washington. It lives from below sea level in the Salton Sink to an altitude of at least 6500 feet in the Sierra Nevada.

The present study was made between June and September, 1955, and is based on 23 adult animals trapped in the Antelope Valley and Walker Pass areas of the Mohave Desert of southern California. The captive animals were individually housed in glass jars or plastic boxes partly filled with fine sand. They were given no water and remained in excellent condition throughout the study on a diet of mixed bird seed.

All temperatures were measured with 30 gauge copper-constantan thermocouples coated with baked insulating enamel and connected to a recording potentiometer. Oral and rectal temperatures were taken with thermocouples inserted to a depth of at least 2 cm.; between these manually taken readings the animals were undisturbed and allowed to move about freely in a terrarium. The continuously recorded temperatures were obtained from implanted thermocouples, the copper and constantan elements of which were arranged end to end and overlapped for approximately 1 mm. The junction was silver-soldered, ground smooth, covered with insulating enamel, and baked. The pocket mouse to be studied was then anesthetized with an intraperitoneal injection of 35 mg. of nembutal per gram of body weight. The thermocouple was threaded through a surgical needle. A perforation was made in the skin of the lateral part of the lumbar region immediately anterior to the kidneys and the needle was inserted transversely through the body of the animal. The thermocouple was then drawn through and adjusted to lie as nearly as

possible in the midline. At the end of the period of measurement the animal was killed and the precise location of the thermocouple determined by dissection. In the animals discussed in this paper the thermocouples were lodged in the muscle and connective tissue adjacent to the aorta. The thermocouple was secured in position by threading its leads through glass beads and gluing the beads to the hair at the points where the leads emerged from the body. After implantation of the thermocouple the animals were given three or four days to recover. Their behavior was normal despite having two leads 5 cm. long extending vertically from their backs. Several of the mice gnawed at the leads, but most did not; and only the animals which appeared indifferent to the implanted thermocouples were used. For recording, the copper and constantan thermocouple leads were spliced to extension wires which were attached directly above the animal container. Rigged in this manner the animals moved about and fed almost unencumbered, and records of deep body temperature could be continuously recorded, in some instances for as long as 3 days.

The ambient temperature was monitored with thermocouples and controlled by insulated chambers equipped with heating and cooling units, blowers, lights controlled by clock-driven switches, and insulated glass ports for observation. Unless otherwise specified, ambient temperature was controlled within 1°C.

RESULTS

BODY TEMPERATURES IN NORMALLY ACTIVE ANIMALS

The range of deep body temperatures of active individuals extends from 32.6 to 39.3°C. The mean rectal and oral temperatures of animals at ambient temperatures of 19–23°C. lie at 37 and 37.3°C. respectively, while the corresponding temperatures of animals exposed to 2.5–3.0°C. lie at 35.6 and 36.0°C. (Fig. 1). The variability in body temperature is conspicuous, and its rate of change is rapid (Fig. 2). The fluctuations are related to activity; the peaks correspond with periods of eating or digging; the depressions, with inactivity or sleep. Body temperature in undisturbed individuals may rise or fall more than 1°C. in less than 10 minutes depending on changes in activity. Under laboratory conditions no diurnal temperature cycle was apparent.

Variations in ambient temperature produce conspicuous changes in body temperature. Continuous records of the response of body temperature to ambient temperature (Fig. 4) show that body temperature drops with falling ambient temperature. Animals kept at ambient temperatures approaching 0°C. still regulate well, however, although at somewhat reduced temperatures as long as food is available. A long-term exposure to 2–3°C. produces a lowering of the body temperature of about the same magnitude as the immediate depression caused by exposure to the same ambient temperature (Figs. 1 and 3). The regulation of body temperature is less effective during increasing than during decreasing ambient temperature. When environmental temperature equals body temperature the animal apparently loses its power to regulate, and thereafter body temperature parallels increasing ambient temperature (Fig. 5).

EFFECTS OF TEMPERATURE ON BEHAVIOR

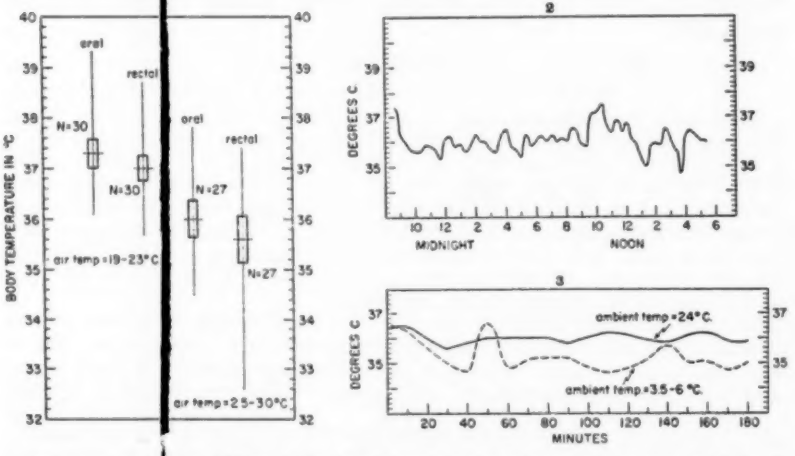
For periods of 2 to 3 weeks twelve individuals were exposed to temperatures varying between 2 and 9°C. with food continually available. They maintained their weight and stayed in good condition. They were much more active than animals kept at room temperature—continually feeding, digging, filling their cheek pouches, occasionally shivering and,

in contrast to the l[a]ter, were never seen sleeping. At moderate temperatures (20 to 30°C.) captive *P. longime[m]bris* were only intermittently active, digging for a few minutes, shifting dirt, grooming, an[d] handling their food stores. Fluctuations in body temperature (Fig. 2) reflect the intermi[t]ent nature of their sleep and activity. We have 24-hour records from five different indi[v]duals held at 20 to 30°C. and none show a clear-cut diurnal cycle of activity as indicat[e]d by body temperature. Periods of sleep longer than an hour were exceptional.

When faced w[i]th increasing environmental temperature, the behavior of the animals underwent no cha[n]ge from normal until ambient temperatures reached body temperature, at which time they showed intermittent periods of hyperactivity. They ate, dug, groomed, and moved dirt w[i]th unusual vigor for a few minutes or seconds, became completely quiescent for a few m[i]nutes and then resumed briefly their furious activity. Aside from the periods of acceler[a]ted activity, the most conspicuous response to elevated environmental temperatures was [a] pronounced bulging of the eyes, a response which is frequently associated with other ki[n]ds of stress. No panting or drooling was observed. As soon as ambient temperature fell b[e]low body temperature, the mice immediately went to sleep and their breathing decrease[d] to approximately half the normal rate for active animals.

HIBERNATION AND AESTIVATION

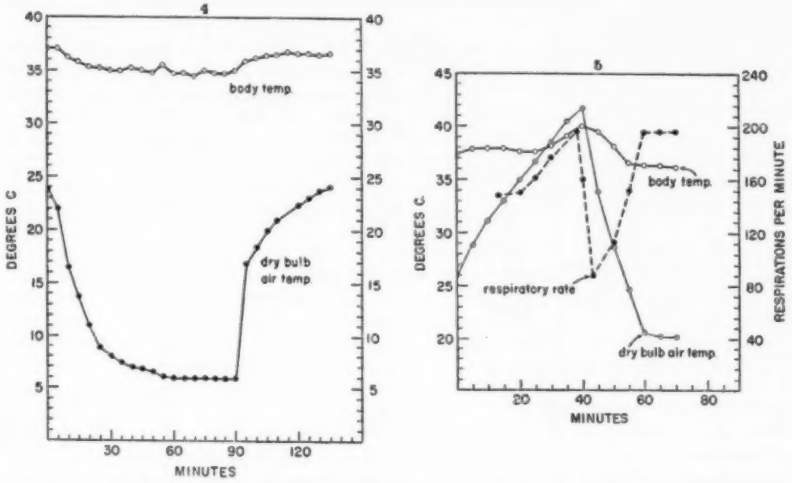
Chilled and ina[c]tive pocket mice are often found in live traps on cold nights and usually they later recover. Such incidents have been observed in many species of small rodents (Howard, 1951). We had casually noted over a period of several years that captive pocket mice, even with food available and in the absence of temperature stress, would



FIGS. 1–3.—(1) The relation of body temperature to ambient temperature in *P. longimembris* after a 10-day exposure. The vertical lines indicate the range; the horizontal lines indicate the mean (M); and the rectangles indicate the interval $M + 2\sigma_M$ to $M - 2\sigma_M$. N indicates the number of temperatures taken. 13 animals were used at the higher temperature and 7, at the lower. Temperatures taken manually with thermocouple.

(2) A continuous record of body temperature in *P. longimembris*, showing characteristic lability. Thermocouple implanted in lumbar region ventral to aorta. Ambient temperature 24°C.

(3) The effects of ambient temperature on body temperature. The records were obtained during one 6-hour period from the same animal. Thermocouple implanted in lumbar region.



FIGS. 4, 5.—(4) Response of body temperature to decrease in ambient temperature. Thermocouple implanted in lumbar region.

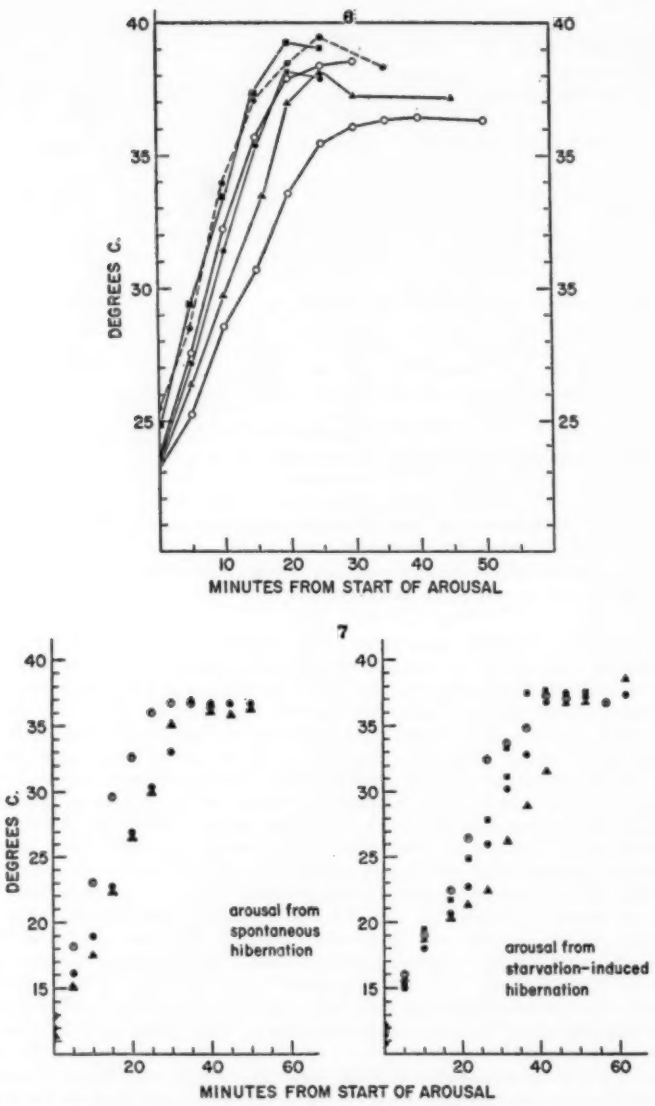
(5) Response of body temperature and respiratory rate to increase in ambient temperature. Thermocouple implanted in lumbar region.

enter either a very profound sleep or an actual condition of torpor. By daily checks of captive pocket mice during the summer of 1955 we observed such instances of torpor in *P. longimembris*, *P. xanthonotus*, *P. formosus*, *P. penicillatus* and *P. fallax*. Moreover, we soon discovered that when animals were removed from food for 24 to 36 hours, torpor was invariably induced. In *P. longimembris* the course of body temperature during arousal from spontaneous torpor followed the same curve as the arousal from torpor induced by fasting. Rectal temperature lagged slightly behind oral temperature during arousal but paralleled it closely. The courses of oral temperature in six individuals during arousal from starvation-induced aestivation (Fig. 6) show striking uniformity. Arousal required between 20 and 30 minutes and the mean rate of heating was about 0.6°C. per minute.

Aestivating animals, which subsequent measurements showed to have body temperatures lower than 25°C., were often seen shifting position, taking a few slow steps, turning around, and slowly scratching their ears. All were capable of some response to the stimulus of handling. As soon as they were disturbed by handling, they were capable of shaky but coordinated locomotion. All could walk and hop when touched; most of them squeaked; all quivered their vibrissae; and most immediately began to shiver as soon as they were awakened. The shivering continued until they warmed to about 30°C. At body temperatures between 30 and 32°C. their coordination was no longer distinguishable from that of normally active animals.

Aestivating animals employed any of the numerous sleeping postures of non-aestivating pocket mice. They assumed their usual sitting posture with head more or less horizontal; they sometimes curved their necks and backs sharply so that their heads were tucked in against their bellies with the tops of their heads resting on their hind feet, or they sometimes lay flat on their sides with hind legs partly extended. The simplest way to distinguish between aestivation and sleep in this species is to observe respiratory rhythm. In aestivation breathing is periodic and shows prolonged apneas; in sleep it is more steady and regular.

Twelve *P. longimembris* were held at 9°C. or lower with food available. On the ninth



FIGS. 6, 7.—(6) Increase in oral temperature of 6 animals during arousal from aestivation. Temperatures taken manually with thermocouples. Ambient temperature 20–22°C.

(7) Increase in oral temperatures of 3 animals during arousal from spontaneous hibernation and of 4 animals during arousal from starvation-induced hibernation. Ambient temperature during hibernation 10°C.; ambient temperature during arousal 20–22°C. Oral temperatures taken manually by thermocouple.

and tenth days individuals entered hibernation. Subsequent experiments showed that hibernation could be induced within 24 hours by removal of food and exposure to an environmental temperature of 9°C. Since the slopes of the curves of increasing body temperature during arousal are similar in both induced and spontaneous hibernation (Fig. 7), we have treated them as the same phenomenon (see discussion).

Behavior prior to entry into hibernation.—Data on this phase of hibernation are difficult to obtain. Our data are based on continuous records from lumbar implantations in two individuals. The two records are similar. For several hours prior to entry into hibernation the body temperature oscillated between 32 and 35°C. with depressions corresponding to periods of sleep and the elevations corresponding to periods of moderate and apparently normal activity.

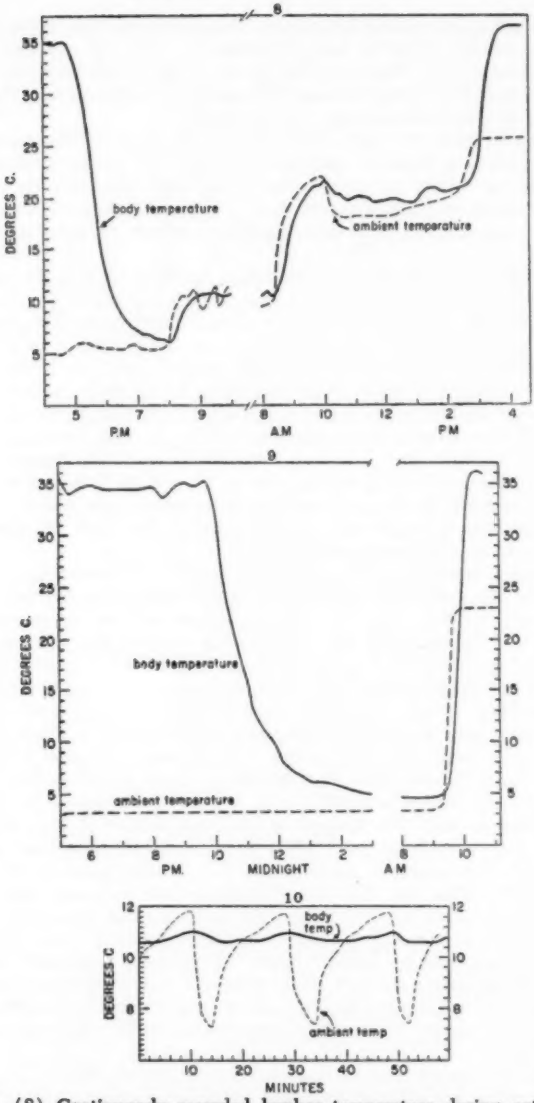
Entry into hibernation.—Entry into hibernation occurred in a single rapid decline of body temperature (Figs. 8 and 9) and was apparently an extension of one of the recurrent downward trends. We observed the behavior of one animal during this decline (Fig. 9). During the 25 minutes that the body temperature was falling from 34 to 27°C. the animal experienced periods of great activity—pushing dirt, trying to climb out of the cage, grooming —alternating with periods of quiet. These periods of hyperactivity caused no increases in the temperature of the lumbar-implanted thermocouple, which suggests vasoconstriction of the locomotor muscles or general vasodilatation. When the body temperature had diminished to 27°C. the animal crouched quietly with squinted eyes. Its respiratory rate, which had steadily declined even during the periods of intermittent hyperactivity, continued to decrease. Prolonged periods of apnea began at a body temperature of 20°C. The decline in body temperature was unbroken and precipitous to 10° and then fell more slowly to a minimum of 6.0°C. (air temperature 5.6°C.).

Behavior during hibernation.—The body temperature of hibernating *P. longimembris* remained slightly above that of the environment and fluctuated directly with environmental changes from 4°C. to 20°C. (Fig. 9). The dependence of body temperature on ambient temperature is well illustrated by Fig. 10, in which an oscillation of environmental temperature from 7.3 to 11.8 elicited an oscillation in body temperature from 10.6 to 11.0°C.

For the most part individuals in deep hibernation assumed the typical crouched sleeping posture. When disturbed from this position they continued to hibernate in any of a variety of positions. They were incapable of righting themselves or of walking, but they could slowly alter their posture and could twitch their vibrissae and slowly move their ears. Breathing was markedly arhythmic with periods of apnea lasting as long as 5 minutes. A more detailed discussion of respiratory rates is given in the section on arousal.

Behavior during arousal.—The increase in body temperature of mice which had been hibernating at 9°C. was almost linear when they aroused in an ambient temperature of 20–22°C. In the early stages of arousal under these conditions much of the heating of course was passive (Fig. 11). The mean respiratory rate increased directly with body temperature to about 29°C. at which point it reached a peak of approximately 390 (range 546 to 273) per minute and then fell sharply to the resting level as the body temperature approached the usual level for active animals. The periodic respiration characteristic of hibernation continued during the early stages of arousal, but the periods of apnea gradually decreased from the 4 to 5 minutes characteristic of deep hibernation to only a few seconds. When the deep body temperature reached approximately 20°C., continuous respiration was the rule (Fig. 11).

Incidental to the measurement of body temperature during arousal, the times of first appearance of various types of behavior were noted for ten individuals (Fig. 12). Even at body temperatures of 6°C. the animals responded to touch and occasionally, spontaneously twitched their ears or wiggled their vibrissae. Pocket mice are usually completely silent. We have heard them vocalize only when engaged in aggressive behavior at which time they utter a penetrating squeak. We were surprised to elicit repeatedly such a vocalization while handling the animals at the very onset of arousal. As might be expected, withdrawal responses to touch appeared first in the front feet and later in the hind feet and still later



FIGS. 8–10.—(8) Continuously recorded lumbar temperature during entry into starvation-induced hibernation, during hibernation, and during arousal from hibernation. Ambient temperature was controlled within one degree of the record shown.

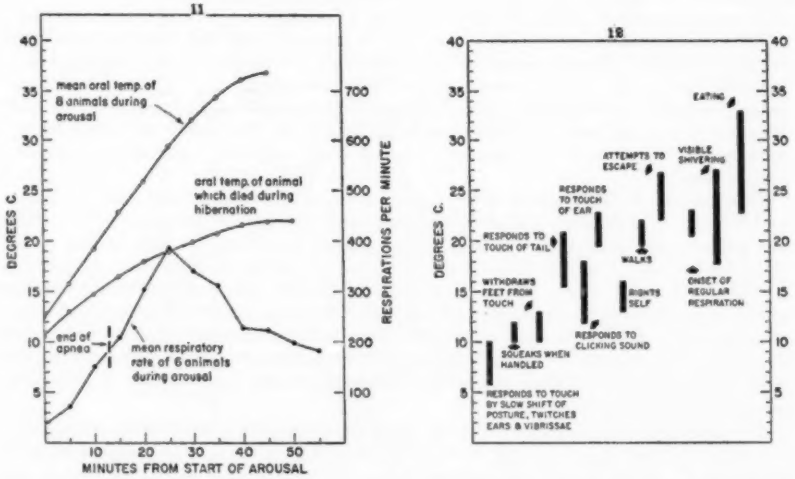
(9) The relation between body temperature and ambient temperature during starvation-induced hibernation, showing the range over which body temperature passively follows ambient temperature. Thermocouple implanted in lumbar region.

(10) The effects of air temperature on body temperature during hibernation. Thermocouple implanted in lumbar region.

in the tail. Touching the ear evoked no response until long after the other extremities reacted to this stimulus. Responses to auditory stimuli were apparent at body temperatures as low as 12 degrees. The complicated neuromuscular response of righting and assuming the normal sitting posture appeared around 14°, but walking first occurred at considerably higher temperatures. Characteristically, visible shivering appeared at body temperatures between 20 and 25°. In five individuals, eating began within one degree of 27° although one animal started to eat (this involves locating the seeds in the sand on the bottom of the terrarium, picking them up in the front feet, and raising them to the mouth) when its oral temperature was only 22.7°C.

Relation of body weight to temperature during fasting.—One group of five animals was held at 21 to 22°, and another group of five was held at 8°, without food. The individuals of each group were weighed to the nearest tenth of a gram at 24-hour intervals, and periodic observations were made on their behavior. Three animals from each group died during or immediately after the experiment. Four of the animals exposed to 8° became torpid in 4 to 12 hours after removal of food; the other became torpid after 26 hours. The animals exposed to 21° remained active for 23 to 27 hours. Animals of the cold group entered deep hibernation and were not aroused by their daily weighing, although they squeaked and moved slightly when handled. One of these animals aroused spontaneously on the fourth day and then resumed hibernation. Animals of the warm group showed the behavior typical of aestivating pocket mice—frequent changes of posture, shaky locomotion, occasional shivering when handled, closed eyes, and frequent arousals from torpor.

The body weights of the animals in both groups decreased during the experiment, but the warm group lost more weight and lost it more rapidly than the cold group (Fig. 13). The initial sharp decline in both groups can be attributed primarily to defecation and does not represent a true loss in body weight.


11
DEGREES C.
RESPIRATIONS PER MINUTE
mean oral temp. of 8 animals during arousal
oral temp. of animal which died during hibernation
end of apnea
mean respiratory rate of 6 animals during arousal
MINUTES FROM START OF AROUSAL
12
DEGREES C.
RESPONDS TO TOUCH OF TAIL
WITHDRAWS FEET FROM TOUCH
SQUEAKS WHEN HANDLED
RESPONDS TO TOUCH BY SLOW SHIFT OF POSTURE, TWITCHES EARS & VIBRISSAE
RESPONDS TO TOUCH OF EAR
RESPONDS TO CLICKING SOUND
ATTEMPTS TO ESCAPE
WALKS
RIGHTS SELF
VISIBLE SHIVERING
EATING
ONSET OF REGULAR RESPIRATION

FIGS. 11, 12.—(11) Relation between body temperature and respiratory rate in 8 animals during arousal from hibernation in an ambient temperature of 20–22°C. Periods of apnea were excluded from calculation of first three points on the curve of respiratory rate. Record of dead animal indicates rate of passive heating.

(12) Range of minimal body temperatures for various responses and patterns of behavior as shown by 10 individuals during arousal from hibernation.

DISCUSSION

"Normal" body temperature.—The high metabolic rate, the large surface to mass ratio, and the resultant rapid loss or gain of heat make the designation of one typical body temperature for a very small species like *P. longimembris* of doubtful physiological meaning. Our observations have shown that in this species body temperature is conspicuously labile; body temperatures of normally active pocket mice usually range between 35 and 38°C., but may fall as low as 32.6 and rise as high as 39.3°C. without being accompanied by any appreciable change in behavior. We interpret this to mean that *P. longimembris* has no one "normal" or "typical" body temperature but functions normally over a range of 5 or more degrees C.

Even brief periods of excitement or activity cause a sharp rise in body temperature, which may amount to as much as 2°C. Most of the temperature records on small mammals available in the literature have been taken manually with thermocouple or thermometer inserted rectally or orally. Our experience with *P. longimembris* indicates that such data represent temperatures near the upper limit of the "normal range." In *P. longimembris* manually taken temperatures average about 1°C. higher than temperatures obtained from implanted thermocouples in undisturbed animals.

Body temperature decreases whenever pocket mice are inactive or asleep. The absence of a diurnal temperature cycle in the experimental animals is to be explained by the absence of a clear-cut diurnal behavior pattern under laboratory conditions. It is possible that intermittent periods of activity throughout the day are characteristic of this nocturnal species under natural conditions, and it may be that these brief fits of activity are necessary to prevent the onset of hypothermia when pocket mice are resting in their burrows at low environmental temperatures. Ambient temperatures near freezing tend to depress the body temperatures of active pocket mice, and apparently they can continue to regulate body temperature at this lowered level only by remaining continually active and only in the presence of a constant source of food. Although Scholander *et al.* (1950) and Scholander (1955) have concluded that body temperature in mammals does not show adaptability to climatic extremes, it seems reasonable to assume that the capacity of *P. longimembris* to maintain most of its normal behavior at low body temperatures is of adaptive importance when it is active at temperatures near freezing. This capacity for normal activity at body temperatures in the lower thirties is probably related to the ability to hibernate, but nevertheless it represents an adaptation of active body temperature to low environmental temperatures.

Hibernation.—*P. longimembris* is the smallest mammal (excepting bats) which is known to hibernate. Unlike many hibernators, neither food storage nor the accumulation of fat are requisite for hibernation, although under normal conditions the little pocket mouse stores food at all seasons. It is unlikely that continuous periods of hibernation longer than a week are common. Under laboratory conditions *P. longimembris* may arouse at intervals of only a few hours to a day or more. In contrast to marmots and ground squirrels, *P. longimembris* enters hibernation with one rapid decline in body temperature and requires only 3 or 4 hours to approximate ambient temperature when exposed to 5°C., as compared with 8 hours in the hamster, which also enters hibernation in one rapid decline in body temperature (Lyman, 1948).

We know nothing about the cause of entry into hibernation when food is available. We were, however, invariably able to induce hibernation within 4 to 26 hours by removal of food from animals in an environment at 5 to 10°C. We were unable to discern any conspicuous differences between starvation-induced and spontaneous hibernation nor in the rates of arousal from the two states. We suggest, therefore, that it is not necessary for these animals to undergo a period of special physiological adjustment as a condition for hibernation. The potentiality for hibernation (or aestivation) presumably exists throughout the year, and may be triggered by various stimuli of which starvation is the most obvious.

The body temperature of hibernating *P. longimembris* passively follows fluctuations in

ambient temperature. Because of its small size, the lag between its body temperature and the ambient temperature is less than has been recorded for other hibernators. In one instance (Fig. 10) we obtained a record of an animal's temperature fluctuating directly with air temperature for many hours, reproducing a damped record of the temperature cycle of the refrigerator in which the animal was being kept. The passive following of ambient temperature by body temperature occurs over a remarkably wide range. A deeply hibernating *P. longimembris* can be warmed to the range of temperatures characteristic of aestivation without evoking arousal, and even a rapid passive increase in body temperature does not necessarily activate the arousal mechanism.

Aestivation.—Even with food available, individuals of this species often allow body temperature to drop to that of the environment when ambient temperatures are between 20 and 25°C. Indeed, the lability of temperature in *P. longimembris* is reminiscent of that found in some bats. In view of the fact that *P. longimembris* can become torpid at any ambient temperature between 2° and 25°C., this species provides an opportunity for examining the relation between "aestivation" and "hibernation." The natural history literature contains many accounts of aestivation, particularly of spermophiles (for example see Alcorn, 1940; Linsdale, 1946), but as Lyman and Chatfield (1955) have pointed out, no data on body temperatures of aestivating animals are available. The data previously presented in this paper show that aestivation and hibernation are very similar in *P. longimembris*, except for the fact that in one the body temperature remains high while in the other it is low. Individuals may be shifted from "deep hibernation" to "aestivation" without arousal merely by increasing the ambient temperature. The body temperature curves during arousal from hibernation and arousal from aestivation have similar slopes. Moreover, both aestivation and hibernation can be induced by the removal of food. The behavior of

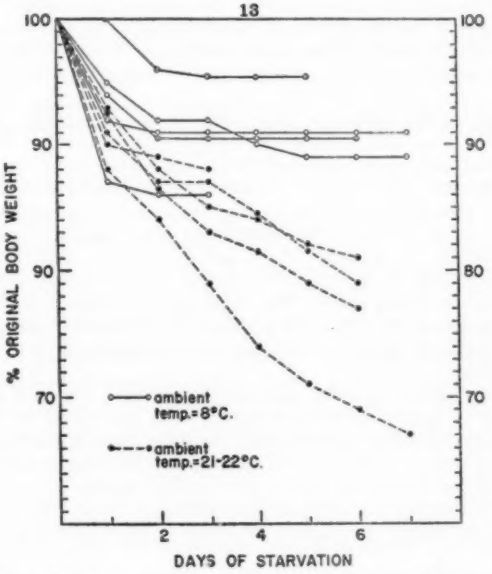


FIG. 13.—Relation of body weight to ambient temperature during starvation-induced torpor. Weights recorded to the nearest tenth of a gram. Mean weight of the 10 animals on the first day was 8.4 gm.

aestivating *P. longimembris* is very similar to that of animals which have attained a comparable body temperature while arousing from deep hibernation. Our data are consistent with the thesis that in *P. longimembris* aestivation is the same physiological phenomenon as hibernation except that body temperature remains high because ambient temperature is high. Whether or not this applies to other species awaits further study.

Ecology.—Very small birds and mammals, because of their high metabolic rates, are faced with an acute need for a continually available food supply unless they have the ability to lower their metabolism drastically during periods of inactivity. The capacity of bats and hummingbirds to become torpid during their daily periods of inactivity (Hock, 1951; Pearson, 1950) reduces the amount of food necessary for their maintenance. Medium to large sized rodents, such as ground squirrels and marmots, meet a comparable problem on a seasonal basis by hibernation and aestivation. The frequency of short periods of dormancy in *P. longimembris* under laboratory conditions and the irregular occurrence of their activity above ground (Hall, 1946:359) suggest that this species is intermediate between the bats and the sciurids in the duration of its periods of dormancy. In contrast to bats, but like squirrels, the body temperature of *P. longimembris* does not necessarily approximate ambient temperature during sleep, although there is doubt that it could maintain a high body temperature during a prolonged period of sleep at ambient temperatures below 10°C. It appears that *P. longimembris* undergoes periods of dormancy that have neither a daily nor a strictly seasonal pattern. Such a capacity, together with food storage and burrowing, provides an effective adaptation for a small mammal living in an environment as severe and unpredictable as the deserts of North America. In times of reduced availability of food, low air temperatures, or snow cover, the ability to become dormant for a few days is probably an important factor in the survival of this species, which occupies a remarkably diverse series of climatic conditions. These brief periods of dormancy should be equally advantageous in the sinks of the Sonoran deserts or on the snow-covered slopes of the Sierra Nevada. Food storage probably represents the first line of defense during unfavorable environmental conditions. By reducing food requirements, periods of torpor would greatly extend the time of survival on a given store of food at any season.

Our experiment on the relation of body weight to air temperature during a period of fasting (Fig. 13), throws some light on the survival value of torpidity in *P. longimembris*. Even with all food stores exhausted, individuals can survive for a week or more at 20–21°C. Judging by the small amount of weight lost per day by the animals at 8°, little pocket mice could survive even longer without food at low ambient temperatures. The difference in the curves of weight loss between the two groups is explained by the delay in onset of torpor, the intermittent activity, and the frequent arousals of the animals at 20–21° as compared with the animals at 8°; and by the presumably higher metabolic rate of the warmer animals during torpor. This explanation is consistent with Kayser's (1952) statement that the amount of weight lost by hibernating European ground squirrels (*Citellus citellus*) is dependent upon the length of time the animals are awake during the total period of dormancy.

Captive *P. longimembris* are highly aggressive toward each other, and a nesting chamber is never occupied by more than one individual. When one animal attempts to enter the nest chamber of another the occupant typically squeaks—apparently an aggressive response, for the intruder usually retreats. It is of interest that this squeak is the first integrated response made by the animals when they are disturbed during arousal. We suggest that even when its body temperature is as low as 10° C., a hibernating little pocket mouse may be effective in territory maintenance by virtue of this vocalization.

ACKNOWLEDGMENT

These studies were aided in part by a contract between the Office of Naval Research, Department of the Navy, and the University of California (NR 160 171).

SUMMARY

Body temperature, hibernation, and aestivation were studied in *Perognathus longimembris*, one of the smallest North American rodents. The range of deep body temperatures of active individuals extended from 32 to 39°C. with a mean of approximately 36°C. Body temperature varied conspicuously with activity. Active animals regulated at ambient temperatures near 0°C. as long as food was available, but when ambient temperature exceeded body temperature they could not prevent hyperthermia.

No clear-cut diurnal temperature cycle was apparent under laboratory conditions. When maintained at temperatures approximating 20°C., the animals occasionally became torpid and allowed body temperature to decline almost to ambient temperature. When removed from food for 24 to 36 hours such torpor was invariably induced. Arousal required between 20 and 30 minutes.

At air temperatures between 0 and 9°C. some of the animals entered hibernation in a few days with food available, and all entered hibernation in 24 hours or less without food. Entry into hibernation occurred in a single rapid decline of body temperature to within a degree or less of ambient temperature. During hibernation the performance of *P. longimembris* was similar to that which has been reported for other hibernating rodents, except that disturbances and changes in environmental temperature were less apt to cause arousal. Body temperature passively followed ambient temperature from 2 to 20° without eliciting arousal. Arousal required about 40 minutes, and the animal's behavior appeared normal by the time deep body temperature reached 30°C.

The appearance of various patterns of behavior during arousal was noted. When handled, the animals squeaked at body temperatures as low as 10°C. Visible shivering began at about 20° while eating commenced at temperatures near 27°C.

Weight loss was less in animals fasted at 8° than at 21° because of the earlier onset of torpor, the lower metabolic rate, and the infrequency of arousal of torpid animals at the lower temperature.

The ecological and physiological implications of body temperature in *P. longimembris* are discussed, and it is concluded that: (1) In this species aestivation and hibernation are the same physiological phenomenon. (2) Torpidity is an important factor in allowing this species to meet both short-term and seasonal periods of environmental stress. (3) The lability of body temperature and the range of body temperatures over which normal activities can be maintained make the designation of a single "normal" body temperature of doubtful physiological meaning for this species.

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THE EFFECT OF WEATHER ON THE WINTER ACTIVITY OF OLD-FIELD RODENTS

BY JOHN B. GENTRY AND EUGENE P. ODUM

As a part of basic studies of ecological change on the AEC Savannah River Plant Area special attention has been given to the old field ecosystem by a faculty-student team of the University of Georgia. Seasonal and annual changes in the "standing crops" of major plant and animal groups have been followed. For sampling small mammals, extensive use has been made of a standard trapline technic originally developed by Calhoun (1948). The basic trapline unit consists of 20 stations with three traps per station set for three nights. We placed stations 25 feet apart so that small as well as large fields could be sampled (for larger fields more than one unit is often used).

Peromyscus polionotus has been, and still is, the most important small mammal in former agricultural fields now abandoned for four growing seasons. *Mus musculus, Reithrodontontomys humulis* and *Cryptotis parva* occur in smaller numbers with an occasional *Sigmodon hispidus* straying into these fields from its normal habitat of older successional stages. Armed with home range data obtained from live-trapping in 1952-54 by Leslie B. Davenport, another member of our team, we have been hopeful of converting numbers per trapline into at least reasonable estimates of animals per acre. Calhoun, Casby and Braut (1955) have recently shown that "space-relative" density can be calculated from ratios between catches of the first two nights, provided the home range is known and the catch on different nights is not greatly

affected by the weather. Since *Peromyscus* in these southern regions reaches a seasonal peak in abundance in winter or early spring (see also McCarley, 1954), sampling should be done then if peak populations of different areas are to be compared (not in late summer or fall as would be the case with many species in the northern United States). Even though winters are relatively mild in the region under study, the question of weather effects becomes a critical one in any attempt to calculate abundance from trapline catch. Accordingly, between January 6 and March 20 a total of 53 traplines were run in a special study of the effect of weather on catch.

Lines were placed in fields of the same general ecological age. The fields were mostly in cotton and corn when abandoned in 1951. Three annual forbs, *Haplopappus* (*Isopappus*) *divaricatus*, *Heterotheca subaxillaris* and *Leptilon canadense* (especially first year) have been prominent fall dominants during the first 4 years of natural succession with various annual and perennial grasses (especially *Digitaria*) and lesser forbs forming an understory.

A schedule was set up so that as many as six lines in six different fields were operating at the same time with the 3-day periods staggered so that some of the lines were ready to be moved to new locations each day. Fields were chosen at random and widely scattered over the huge 200,000-acre SRP reservation which is located on the Upper Coastal Plain of South Carolina. Forty-one different fields were trapped once, and six fields twice (but at a different location in the field), in January and again in March. While the fields are uniform in age, a variety of soil types are present ranging from deep sands (Lakeland series) to soils with fairly heavy clay subsoils (Ruston, Cahaba and Orangeburg series). Consequently, fields vary in productivity and density of vegetation. It is not surprising, therefore, that catches ranged from zero to as many as 17 per trapline.

The typical pattern of mid-winter weather in the region consists of periods of clear, cold (or cool) weather (night low 20° to 40°F.) alternating with periods of cloudy, warm weather, often with rain (night low 40° and above). Usually there is no difficulty in assigning a given night to one or the other of these two categories. The trapline data clearly showed what we had already suspected, namely, that weather does have a marked effect on catch with warm, cloudy nights favoring a larger catch than clear, cold nights.

In Table 1 the catch of *P. polionotus* and other species on each of the three successive nights is shown for each of the 53 traplines. The traplines are divided into five groups according to major weather conditions. Average catch is graphed in Figure 1 for all species along with the "expected" 3-night trend based on a very large number of lines from various regions as summarized by Calhoun, Casby and Brant (1955). A semi-log plot is used so that rates of decrease or increase may be compared directly. The trends are the same regardless of whether *P. polionotus* is considered alone, or all species together. When the weather remained clear and cool for all three nights the rate of decline in catch (curve 4, Fig. 1) was similar to the "expected" (curves 1

TABLE 1.—*Catch of small mammals on three successive nights for each of 53 standard traplines grouped according to major weather conditions prevailing during the three-night period. SRP Area, Jan.-Mar., 1955. In each column, which represents the successive nights, the first figures are numbers of Peromyscus polionotus, the figures in parentheses are numbers of other species, if any.*

	I. No major weather change during the 3-night period.					
	(a) Clear, cool throughout			(b) Cloudy, warm throughout		
	9	1	2			
	0(1)	1(5)	1(3)			
	8	4(1)	3			
	0	0	1			
	0	1	1			
	0	0	0	1	1	0
	3	3(2)	1	1	1	0
	6	3	3(2)	7	1	0
	4	0	0	3	0	0
	1	0	0	5	0	0
	0	0	0	5(1)	0	1
	1	0	2	3	1(1)	1
	0	0	0	11	3	3
Totals	32(1)	13(8)	14(5)	36(1)	7(1)	5
Av. *P. polionotus*	2.5	1.0	1.1	4.5	0.9	0.6
Av. all species	2.5	1.6	1.5	4.6	1.0	0.6

	II. A major change in weather during the 3-night period.								
	(c) Clear, cool changing to cloudy, warm the 2nd night.			(d) Clear, cool changing to cloudy, warm the 3rd night.			(e) Cloudy, warm changing to clear, cool the 2nd night.		
	0(1)	0(4)	0(2)						
	0	0	1(1)	2(6)	0(1)	1(2)			
	2	4(1)	3(1)	4	2	2			
	6	8	1	1(2)	2	0			
	0	0	1	1	1	5(1)			
	1	4	0	1	1	0			
	1	6(3)	2(1)	2(1)	2	3	0(3)	1(3)	1(2)
	1	1	0	0	0	0	4	1	0
	1	1	0	2	2	4	0	0	0
	2(1)	10	1	0	0	1	0(1)	0	0
	0	1	3	1	2	0	3	1	0
	0	0	2(1)	0	0	2	0	0	1
	1	2	0	1	0	0	1	0	0
Totals	15(2)	37(8)	14(6)	15(9)	12(1)	18(3)	8(4)	3(3)	2(2)
Av. *P. polionotus*	1.2	2.8	1.1	1.2	1.0	1.5	1.1	0.4	0.3
Av. all species	1.3	3.5	1.5	2.0	1.1	1.8	1.7	0.8	0.6

and 2). When it was warm and cloudy more mice were caught the first night and less the last night than "expected," resulting in a steeper downward trend (curve 3). When the weather changed from cool, clear to warm, cloudy on the second night a sharp rise in catch occurred on the second night (curve 6). A change to warm, cloudy condition the third night also produced an upward

trend (curve 5). A change from cloudy to clear (curve 7) resulted in a change in rate which also indicated a decline in catch in clear weather.

As may be seen from Table 1, most of the individual lines show the same trend as the averages with the effects of weather being most pronounced, as would be expected, in fields with large populations. The first night's catch

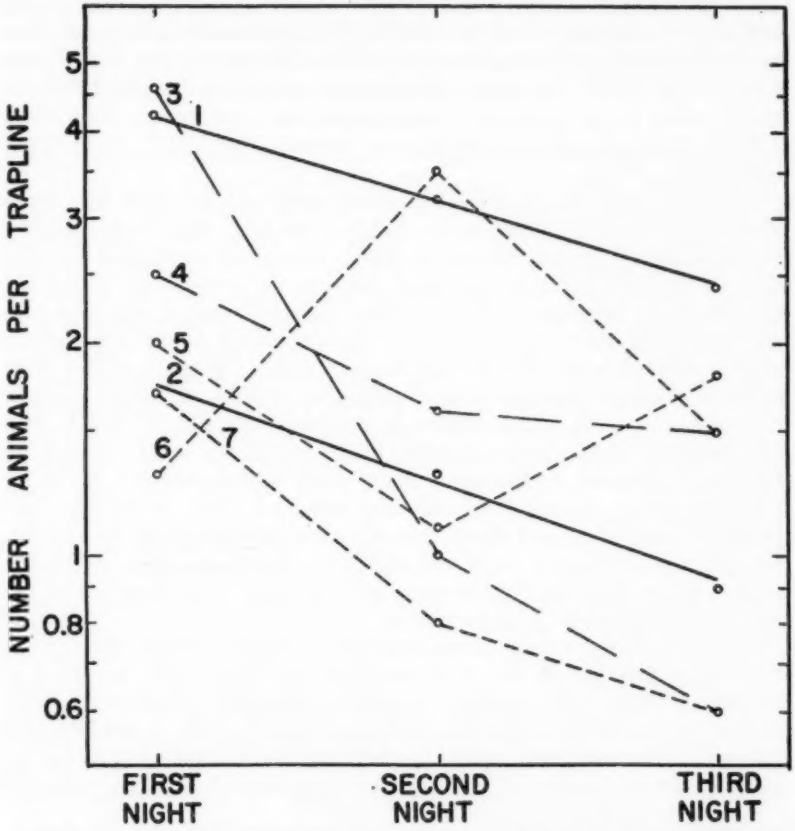

FIG. 1.—Catch of all species on successive nights by standard 20-station, 60-trap traplines in old field habitats on the SRP under 5 different weather conditions, Jan.-Mar. 1955 (broken lines), as compared with "expected" trends (solid lines). 1. Average "expected" trends based on 845 traplines reported by Calhoun, Casby and Brant (their Table 6). 2. Average "expected" trends based on 575 of the above traplines which sampled low populations (0–9 total catch per line). 3. Trends when the weather remained warm and cloudy throughout the 3-day period (8 lines). 4. Trends when the weather remained cool, clear throughout (13 lines). 5. Trends when weather was clear, cool the first two nights and changed to warm, cloudy the 3rd night (12 lines). 6. Trends when weather changed from cool, clear to warm, cloudy the 2nd night (13 lines). 7. Trends when weather changed from warm, cloudy to cool, clear the second night (7 lines).

was usually the largest when the weather was consistent, but in not one of the 13 lines operating when the weather changed to cloudy the second night (Table 1, c) did the largest catch occur on the first night as would be "expected." Especially convincing were the results of lines run simultaneously. For example, during the three-day period Feb. 1–3, the first night was clear, moonless, minimum temperature 39°F.; the second night warm, rainy, cloudy with a 65°F. minimum; and the third night partly cloudy and cooler. Five lines in five different fields produced the following: 0-0-1; 1-4-0; 1-9-3; 1-1-0; 3-10-1; total: 6-24-5. In contrast, five lines set out during the period Feb. 28-Mar. 2, when it was warm and cloudy throughout (min. temp. about 50°F., with rain the third night), caught mice as follows: 1-1-0; 1-1-0; 7-1-1; 3-0-0; 5-0-0; total: 17-3-1.

While it is quite clear that the three-night trend and the catch on a given night were definitely related to the weather, the total catch of the trapline for the three-night period was not so greatly influenced by weather changes. None of the differences in total catch between the five groups in Table 1 are statistically significant. Thus, 32 lines operating when it was clear-cold for two or more nights (groups a, d and e) averaged 4.8 animals per trapline, while 21 lines with two or more cloudy-warm nights (groups b and c) averaged 6.3. Though seemingly a large difference in favor of cloudy weather, it is not large enough to be statistically significant ($t=1.16$; $P=0.25$). If a larger number of lines were available, or if comparisons could be made on the same populations, a difference probably could be demonstrated. However, it is rather obvious from Table 1 that what actually happens is that when the weather remains warm and cloudy from the onset the population, for all practical purposes, is trapped out in two nights, or even in one night. When the weather is less favorable for above-ground activity, at least three nights are required to trap out the local population.

If extreme weather conditions are avoided, the standard 3-night line appears to provide a good sample for comparing areas and years despite the effect of weather on single night captures. However, calculating abundance on the basis of the ratio between the first and second night's catch, as suggested by Calhoun, Casby and Brant (1955), is definitely counter-indicated under the winter conditions considered in this paper, unless enough lines are averaged to cancel out weather influences.

Temperature, humidity and low light intensity are probably involved in the increase in activity under cloudy conditions, although our data are not yet sufficient to justify a breakdown beyond the five categories shown in Table 1. Light rain almost always favored an increased catch, provided the population had not already been trapped out. During the warmer parts of the year a tendency for increased catch on cloudy and rainy nights was also evident, although the effect was not so pronounced as in winter when cloudy conditions are usually accompanied by rising temperatures. Since the old-field mammals live in a relatively dry environment, it may be that moisture is an important

factor in the regulation of activity, and perhaps also seasonal abundance. Blair (1951) found that live trap captures of *leucocephalus*, a beach-inhabiting subspecies of *polionotus*, were reduced on moonlight nights; he stated that "the degree of illumination by the moon was the most important factor governing the amount of activity on a given night." In our case trends, as shown in curves 4, 5, 6 (Fig. 1), occurred when lines were run during full moon as well as dark-of-the-moon periods. However, direct evaluation of the moonlight factor was not possible since there were actually comparatively few bright moonlight nights during the period of study.

SUMMARY

Since the establishment of the AEC Savannah River Plant in 1951, extensive use has been made of the Calhoun trapline technic of sampling small mammal populations, especially in the study of the abandoned field ecosystem. Since field rodents (*Peromyscus polionotus* being the most important species) reach a seasonal peak in abundance in winter or early spring, annual comparisons are best made at this time. However, weather affects catch at this time and must be considered in estimating density from trapline data. Warm, cloudy nights result in a larger catch than cold, clear nights. When the weather remains unchanged during the 3-night period an "expected" downward trend in catch occurs, but when the weather changes from clear to cloudy on the second night, average catch per trapline rises sharply (Fig. 1). Data from 53 traplines in 41 different fields are graphed to show catch trends for five major weather conditions. While weather definitely influenced the 3-night trend and the catch on a given night, the total catch for the 3-night period was not significantly different under the five weather conditions; under warm, cloudy conditions the population was trapped out before the end of the 3-night period, while all three nights were required to "harvest" the population under cool, clear conditions. The use of the ratio between first and second night captures in calculating density, however, is counter-indicated for the seasonal conditions considered in this paper. Moisture, as well as temperature and moonlight, may be an important factor in regulating above-ground activity.

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COOLING AND THERMAL CONDUCTIVITY IN THREE SMALL ALASKAN MAMMALS

By Peter R. Morrison and William J. Tietz

Mammals are able to maintain their body temperatures in the face of cold stress through the insulation provided by their fur. In this study we explore a method for evaluating this insulating layer in dead animals and measure the modification of its effectiveness by changes in extent, thickness or air movement.

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MATERIALS AND METHODS

Tundra redback voles (*Clethrionomys rutilus dawsoni*), tundra voles (*Microtus economis macfarlani*), and long-tail shrews (*Sorex cinereus hollisteri*) were trapped near Fairbanks, Alaska, in February and March of 1952. Bodies were obtained either from animals found frozen in live traps or from animals which died as a result of exposure or other laboratory tests. The temperature of the area from which the animals were taken varied from 0 to –43° C. and occasionally as low as –56° C., but the microclimate under the snow is much milder (Johnson, 1951).

The five *Sorex*, thirteen *Clethrionomys* and nine *Microtus* studied had average weights of 2.3, 14.3 and 20.4 gm., respectively. All animals were handled as little as possible and then only by feet or tail to prevent soiling by oils, moisture, or dirt which might cause clumping and breaking of the fur. It was difficult to keep the fur clean and even the fur of live animals in captivity seemed to have an affinity for foreign material.

Two methods were used to determine the rate of heat loss through the fur: (1) measuring the change in temperature of an animal body held at a constant ambient temperature; and (2) recording similar data from a fur-covered, metal cast of an animal's body. The temperatures of the bodies and casts were taken to 0.1° C. on a Leeds and Northrup recording potentiometer employing iron-constantan thermocouples and printing at 32 second intervals.

Body Cooling.—The animals were allowed to cool (or warm) at constant ambient temperature. Representative records for a shrew and a mouse are shown in Fig. 1. Cooling is rapid at first, when the temperature gradient is high, and becomes slower as the body temperature approaches the ambient temperature. With the simplest assumptions, the rate of cooling of any object under such conditions should be proportional to a cooling constant, C, and to the temperature differential between the body and its surroundings, *if* there is a negligible temperature gradient in the tissues. Thus,

$$dT_B/dt = C(T_B - T_A)$$

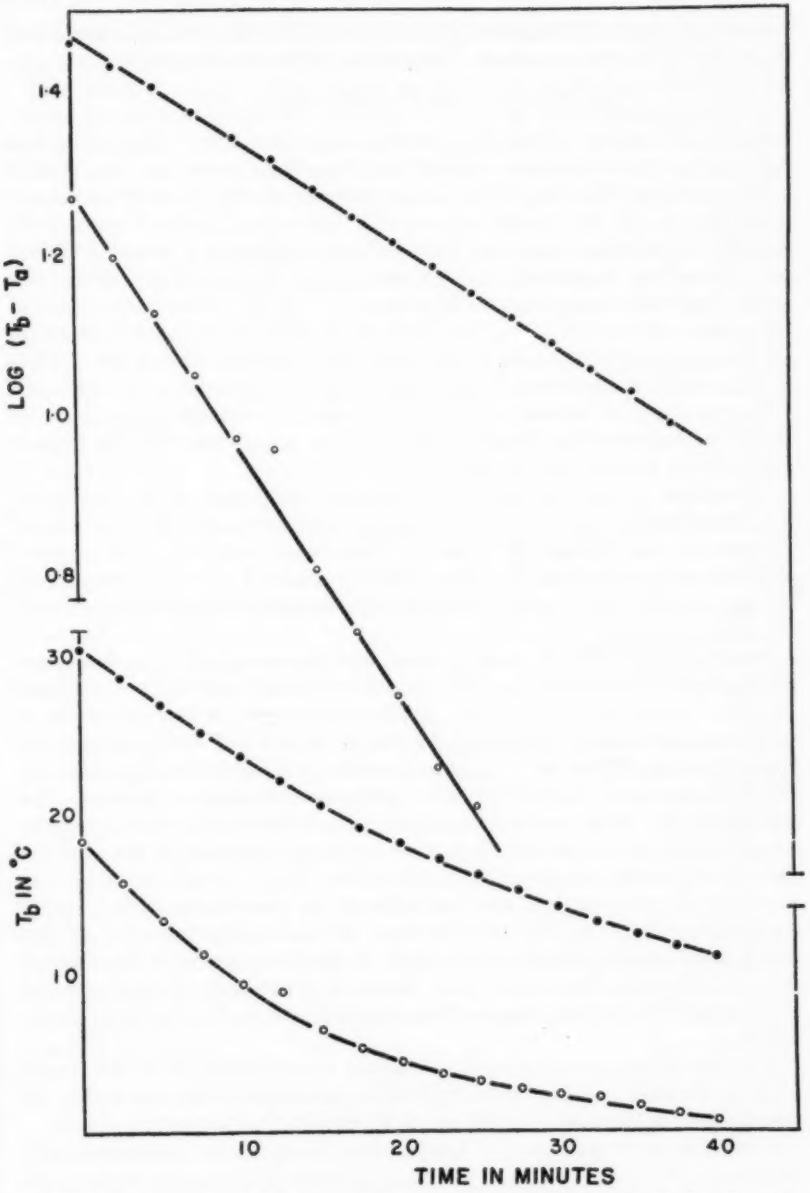

FIG. 1. — Lower: the fall in temperature (T_b) of cooling animal bodies plotted against time; ambient temperature (T_a), 0°. Upper: Log of the temperature differential ($T_b - T_a$) plotted against time. Open symbols., *Sorex*; closed symbols, *Microtus*.

where T_B is the body temperature, t is the time, C is the cooling constant and T_A is the ambient temperature. Integration yields the relation,

$$\ln(T_B - T_A) = Ct + c = 2.3 \log(T_B - T_A),$$

which is the familiar relation for a self-limiting, "first order" reaction. If it is valid in the present instance a plot of log $(T_B - T_A)$ against time should yield a linear relation. That this is the case is indicated in Fig. 1 which also shows these plots for the two cooling experiments. The cooling constant can then be directly calculated at $2.3\Delta \log (T_B - T_A)/\Delta T$. Values of 1.74 and 4.27 hr.$^{-1}$ were calculated respectively in these two cases. In descriptive terms, this means that with a temperature differential of 1° C. the *initial* cooling rate of the mouse will be 1.74° C. hr.$^{-1}$ and that of the shrew 4.72° C. hr.$^{-1}$. Stated in another way, the temperature of the mouse will fall 50 per cent of the distance to the ambient temperature in 0.4 hours and that of the shrew in 0.16 hours. The values may be converted into units of thermal conductivity, in cal. °C.$^{-1}$ hr.$^{-1}$, by employing the specific heat of mouse tissue, 0.83 cal. °C.$^{-1}$ gm.$^{-1}$, (Hart, 1950) and the body weight.

The effects of four variables (fur condition, body posture, air movement, and the difference between warming and cooling) were considered for each of the species. Due to autolysis it was only possible to carry out a few measurements on each individual. In some cases the effect of variables was directly compared on the same animal but, generally, average values for the particular condition were used.

Cast Cooling.—After the cooling curves had been measured on an intact animal, the skin was removed carefully to avoid stretching and the carcass pinned in either "curled" or an "extended" position and frozen. A layer of plaster of paris was poured into a form and the frozen carcass half immersed with the ventral side up. When set, a coating of vaseline was applied to the upper surface and the carcass covered entirely with a second batch of plaster. After hardening, the carcass was removed and holes drilled in the plaster negative for wire leads and for filling. A thermocouple was arranged in the center of the opening which was then filled with molten Wood's metal. After the cast was cleaned and smoothed, the moist skin of the animal was slipped on and the opening sewed up. The bond between the cast and the skin was so close that it was necessary to use a razor blade to effect removal once the skin had dried on the cast. The models were heated to about body temperature, and the cast and the ambient temperatures were followed on the thermocouple recorder.

The rate of heat loss in the metal "animal" was computed from the cooling constant obtained as above by multiplying by the weight of the cast and by the specific heat of the metal (0.0352 cal. °C.$^{-1}$ gm.$^{-1}$).

Conditions of Measurement.—Temperature changes were measured under conditions of both cooling and warming. During warming the bodies were placed in a closed box about eight feet from the floor to minimize the temperature fluctuation and air movement found lower. The ambient temperature

was checked periodically and remained sufficiently constant during the course of a run and generally varied only by 0.5°C.

In cooling, the bodies were placed on cardboard on the top shelf of a refrigerator which was regulated at about 0° C. With this arrangement transient temperature fluctuation was caused by opening the door to check the ambient temperature and there must have been some convective air currents resulting from the difference in temperature between the freezing unit and the outer wall.

Fur Condition was considered as smooth (*down*) or fluffed (*up*). Fluffing of the fur was accomplished by blowing against the angle of the hair insertion several times over the whole surface. To the eye, a fairly uniform stand of hair was obtained by this procedure.

Body Posture was taken as extended or curled. In curling, the position of the animals as frozen to death was approximated as closely as possible. Because of the added curvature of the body surface in this position the fur was neither smooth nor fluffed but rather a compromise between the two. Since it was not possible to smooth the fur it was allowed to seek its natural level after blowing lightly over it. To the eye, this appeared very similar to the condition of the fur on live animals which were curled up or on the bodies of animals which had frozen to death. Certain of the latter were measured in this natural posture, having died of exposure in the traps, and these results indicated that the artificial curling was similar to the natural.

Extended casts were made for all three species, but casts of curled bodies were made only for the two species of mice. The fur on the extended casts was studied both smoothed and fluffed since the two conditions could be maintained here.

Moving air was supplied at room temperature by an enclosed fan with a 2 × 3 in. opening. The air velocity was measured by a hot thermometer-type anemometer which depended on the squilibrium cooling of the heated bulb of a mercury thermometer for its action. Measurements of the air movement were made at the top and both sides for each animal. Velocities were always between 2.5 and 3.5 m.p.h. and never varied more than 0.5 m.p.h. for any one species. The animals were located about 2 ft. from the mouth of the blower and the air streak adjusted so as to just riffle the guard hairs on the back and upper sides. The axis of the body was parallel to the wind stream with the head pointed away from the fan. The assembly was placed in a large box (3 × 3 × 2 ft.) to minimize temperature fluctuations and the influence of extraneous air currents.

RESULTS

Cooling Constants on Animals.—The average values for constants describing temperature changes under various conditions are presented in Table 1. Values for the two species of mice ranged from 1.4 to 2.3, and for the much smaller *Sorex*, from 2.8 to 5.9. An uncomfortably high variability within a single condition and group was observed particularly in *Sorex*. This probably reflects

TABLE 1. — *Cooling constants in hr^{-1} with varying fur condition, body posture, and air movement*

POSTURE	FUR	WIND	WARMING	COOLING	COOLING / WARMING	MEAN
			CLETHRIONOMYS			
Extend	down	0	1.67± .67[1](6)[2]	2.20± .41(6)	1.32[3]	1.96± .42(12)
Extend	up	0	1.61± .24(7)	2.32± .39(7)	1.44[3]	1.96± .48(14)
Extend	down	+	2.08± .28(2)			
Extend	up	+	1.62± .36(2)			
Curl	–	0	1.37± .36(8)	1.63± .21(7)	1.19	1.48± .33(15)
			MICROTUS			
Extend	down	0	1.57± .19(7)	1.78± .20(3)	1.13	1.64± .20(10)
Extend	up	0	1.80± .57(4)	1.69± .46(5)	0.94	1.76± .48(9)
Extend	down	+	1.99± .50(3)			
Extend	up	+	1.77± .55(3)			
Curl	–	0	1.51± .47(6)	1.50± .43(4)	1.00	1.51± .43(10)
			SOREX			
Extend	down	0	3.36±1.16(4)	3.45±1.22(6)	1.03	3.39±1.12(10)
Extend	up	0	3.33± .62(4)	3.38± .54(4)	1.01	3.37± .54(8)
Extend	down	+	4.65±1.00(2)			
Extend	up	+	5.90±2.10(3)			
Curl	–	0	3.63± .64(2)	3.91± .14(2)	1.08	3.76± .40(4)

[1] $\pm p = (\Sigma\ d^2/N-1)^{1/2}$

[2] Number of values

[3] Only these two values represented a significant difference between warming and cooling.

both differences in individual specimens and experimental difficulty in handling and reproducing the body and fur position in these small animals. No difference was seen between the warming and cooling constants in *Microtus* and *Sorex*, but in *Clethrionomys* the cooling constant was about a third higher. This effect might result from several factors including air movement and convection within the refrigerator, radiation loss to the cooling coil and evaporation of water from the skin. But there is no apparent reason why any of these factors should be more effective in one species than in another.

The effects of the several variables in terms of the per cent change produced are summarized in Table 2. In still air there was no increase in insulation due to fluffing. With wind, there was indication that fluffing the mouse fur afforded better protection, but only the values for *Clethrionomys* approach significance. In *Sorex*, fluffing caused heat to be dissipated at a 27 per cent more rapid rate, but because of the extreme variability of this form even this large difference was not significant.

The effect of body posture is also summarized in Table 2 as the per cent change from the extended form produced by curling. In *Clethrionomys* a highly significant 25 per cent decrease in heat transfer was produced both

with smooth and fluffed fur. In *Microtus* and *Sorex* the respective decrease and increase produced by curling were again not significant.

A significant increase in conductivity in *Clethrionomys* and *Microtus* was produced by air movement over the smoothed surface, but no effect was seen over fluffed fur. *Sorex* showed a marked increase in conductivity under both conditions, particularly with fluffed fur. Maximum differences were observed in mice between the curled animals in still air and the extended animals in moving air with fur smoothed down. This represented an increase of 67 per cent in *Clethrionomys* and 33 per cent in *Microtus*. In *Sorex* the maximum increase was 80 per cent for an extended, fluffed animal in moving air as compared to the same animal in still air.

Constants on Fur Covered Casts.—Thermal conductivity values for the extended fur-covered casts were almost identical in *Sorex* and only slightly less in mice (16% in *Clethrionomys* and 18% in *Microtus*) than similar values determined on animal bodies.

Only cooling curves at room temperature were measured on the casts. These are summarized in Table 3. There were insufficient values to warrant statistical analysis. Fluffing the fur caused a decreased rate of heat for all casts. The curled *Clethrionomys* cast showed 11 per cent less heat loss with smooth fur and 19 per cent less with fluffed fur. In *Microtus* the average change was 12 per cent. Our basic premise that no substantial temperature gradient existed in the animal tissues during cooling may be recalled here. If this premise had been false, a greater heat loss in the metal-covered casts than in the carcasses would be expected because of the metal's much higher thermal conductivity. Accordingly, whatever this method's uncertainties are, they do not appear to be related to internal temperature gradients. The lower rate of heat transfer from the casts may relate to the drier condition of the skin covering. Scholander *et al.* (1950) noted some difficulties of this sort in applying wet skins to measuring hot plates.

TABLE 2. — *The effect of fur condition, body posture, and air movement in modifying heat loss in small mammals*

SPECIES	CLETHRIONOMYS			MICROTUS			SOREX		
Effect	Ind.[1]	Ave.[2]	t[3]	Ind.	Ave.	t	Ind.	Ave.	t
Fluffing									
Calm	0	0	—	+18	+ 7	<1	+15	− 1	<1
Wind	− 8	−22	1.4	−14	−11	<1	+29	+27	1.0
Curling	−17	−24	3.3	−10	−11	1.3	+ 9	+11	2.2
Wind									
Smooth	+31	+ 25	2.4	+33	+27	1.9	+45	+35	1.4
Fluffed	+ 2	+ 6	<1	+24	− 2	<1	+70	+52	3.2

[1]Average change in pairs of individual values in per cent
[2]Per cent change in average value
[3]"t" refers to "average" column

TABLE 3.—*The effect of fur condition and body posture on cooling in fur-covered casts*

EFFECT	CLETHRIONOMYS	MICROTUS	SOREX
Fluffing			
Curl	−16	−17	
Extend	− 7	− 4	−13
Curling			
Smooth	−11	−18	
Fluffed	−19	− 6	

The comparison of casts with and without fur did not give uniform results possibly because the unprotected dead air layer around the uncovered cast was very sensitive to stray air currents. In *Microtus* and *Clethrionomys* the fur covering reduced heat loss somewhat in one case, but actually increased the loss in the other. *Sorex* showed a modest decrease in heat loss (30%) when the fur was applied. This apparent anomaly may relate to the fact that while providing an insulating layer, the fur also increases the surface available for heat transfer. The data of Scholander *et al.* (1950) on heat conduction through furs of different length indicated that the insulation provided by the dead air layer covering an otherwise unprotected surface was "equivalent" to about 3 mm. of fur. With air movement this layer would be quickly destroyed and the uncovered cast would contrast strongly with the fur cover surface which was but little affected by wind.

DISCUSSION

The heat transfer from a hot body may be related to (1) the extent of the surface through which heat is flowing, and (2) the thickness and (3) the nature of the insulating layer. In fur, and most ordinary insulating media, the latter point largely relates to the effectiveness with which air is trapped in a "dead" layer to minimize convective heat transfer. Accordingly, an increase in the thickness of the surface layer as by fluffing should reduce the heat loss and the reduction of the surface area by curling should also conserve heat, while air movement should act to increase the conductivity by modifying the surrounding dead air space.

Fur Condition.—Fluffing the fur increased the thickness of the insulating underfur from a minimum of 2–3 mm. to 9 in the mice and from 3 to 8 mm. in the shrew. If the insulating effectiveness of these two layers were proportional to their thickness, as is the case in non-biological systems and has been shown to be roughly true in furs of varying length from a number of larger animals (Scholander *et al.*, 1950), then the conductivity should be reduced accordingly to about a half.

In our cooling measurements on the dead animals, however, the fluffing had no significant influence on heat loss. In the fur-covered casts, fluffing reduced the heat loss only by about 10 per cent. These changes are much less than expected and indicate that, per unit of total thickness, the fluffed fur is a much

poorer insulation than the smooth fur. Several factors may have reduced the effectiveness of the fluffed fur in these experiments as compared to the living animals. The most likely of these is the production of rifts or irregularities in the fur which would permit convective heat exchange.

Body Position.—Curling reduces the surface area by about a fourth to a third (Morrison and Meyer, 1956) and a comparable decrease in conductivity might be expected. In *Clethrionomys* mean values of –24 per cent for the change in heat transfer from the animal bodies and –15 per cent from the fur-covered casts were found (Table 2). In *Microtus* bodies a smaller decrease of 11 per cent was observed on curling and in the cast a change of 12 per cent. These latter values represent considerably less than the expected 25 per cent but it was not possible to curl the carcasses for casting as tightly as the living or dead animals. In *Clethrionomys* which closely checked the expected decrease, some of the dead animals had frozen to death in the curled position. This curling was very tight as little or no relaxation occurred between the time of death and freezing.

In *Sorex* an increase in heat loss of 11 per cent was effected rather than a decrease. This may represent the influence of curling in opening the fur at the tips as it radiates from a surface of high curvature in these tiny animals, thus impairing its insulating ability.

Wind.—All forms showed an increase in conductivity with wind, averaging about 33 per cent with smooth fur. The impairment correlates with field observations that the mice not only did not emerge when the wind was noticeable but did not even open their holes until calm conditions had persisted for some time.

The *Clethrionomys* with fluffed fur were unaffected by wind, a property which may relate to their greater resistance under natural conditions. With air movement, *Sorex* showed a further increase in conductivity with fluffed fur which apparently allowed considerably more convection in the fur in this form than in the mice. It appears that the maximum insulation potential of this fur is not developed at maximum elevation but at some intermediate point. *Sorex*, which showed the greatest susceptibility to wind, were never observed active on the surface with the single exception of a 2.7-gm. individual which was taken in direct sunlight on a very warm April day.

Heat Transfer.—In Table 4 the "cooling" constants for the three species have been converted into units of thermal conductivity expressed in terms of the animal, of unit weight, and of unit surface. The values for oxygen consumption are minimums corresponding to a curled condition. The agreement between the *in vitro* data from dead animals and casts, and that from the living animals, is within 20 per cent, a quite satisfactory correspondence in view of the rather great differences in conditions and methods, and our neglect of several quite appreciable factors, e.g., respiratory heat loss, surface movement in the living animal.

These conduction rates of about 0.5 cal $cm^{-2}hr^{-1}°C.^{-1}$ correspond to an effective fur length of 4–5 mm., according to the average curve of Scholander

et al. This condition rate may also be expressed as 1 *clo* unit of insulation, which is to say that these small mammals are as well clothed as the average man wearing a business suit.

TABLE 4. — *Comparison of values for heat loss by different methods*

	CLETHRIONOMYS, 14.3 g.			MICROTUS, 20.4 g.			SOREX, 2.3 g.		
	$\frac{cal}{h. °C}$	$\frac{cal}{g.h. °C}$	$\frac{cal}{cm^2 h. °C}$	$\frac{cal}{h. °C}$[1]	$\frac{cal}{g.h. °C}$	$\frac{cal}{cm^2 h. °C}$	$\frac{cal}{h. °C}$	$\frac{cal}{g.h. °C}$	$\frac{cal}{cm^2 h. °C}$
Extended									
Body	23.3	1.63	.47	28.9	1.41	.43	6.4	2.8	.31
Cast	17.3	1.21	.346	22.8	1.12	.34	6.7	2.9	.32
Curled									
Body	17.6	1.23	.476	25.5	1.25	.555	7.2	3.1	.53
Cast	15.3	1.07	.413	17.7	0.89	.396			
O_2 cons.[2]	16.6	1.16	.448	22.2	1.09	.483	8.1	3.5	.59

[1]Based on surface area measurements for these species (Morrison and Meyer, 1956).

[2]Based on measurements on summer animals of these species (Morrison and Ryser, 1951; Morrison, *et al.*, 1953).

SUMMARY

A procedure for the analysis of cooling curves of dead animals to provide a measure of the thermal conductivity of the fur is described. A considerable variability was observed between individual measurements, but the mean results compared well to those obtained on fur-covered metal casts and by measuring oxygen consumption in living animals. The effects of posture (reduction of body surface), fur position (depth and density of the layer), and air movement were considered. Although the magnitude of the observed differences was small, they are in agreement with field observations which show *Clethrionomys* to be better adapted to winter conditions than *Microtus*, and *Sorex* substantially poorer than either of these. In general, however, the insulation was substantially constant under varying conditions.

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POPULATION STUDIES ON SMALL MAMMALS OF SOUTHEASTERN MANITOBA

By C. H. Buckner

Recent studies by the author (1955*b*) have shown that small mammals are important predators of the larch sawfly, *Pristiphora erichsonii* (Htg.), in eastern Manitoba. During these studies, considerable information was collected on the populations and biology of the more important species of small mammals inhabiting the tamarack bogs of the study region. The animals discussed include the cinerous shrew, *Sorex cinereus cinereus* Kerr, the saddle-backed shrew, *S. arcticus laricorum* Jackson, the red-backed vole, *Clethrionomys gapperi loringi* (Bailey), and the field vole, *Microtus pennsylvanicus drummondii* (Audubon and Blackman), with notes on less abundant species. Portions of this paper are based in part upon a M.Sc. thesis presented to the University of Manitoba. This is Contribution No. 280, Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada.

THE STUDY AREA AND PLOT DESCRIPTIONS

Investigations on the population and ecology of the small mammals frequenting tamarack bogs were conducted from 1952 to 1955. Operations were centered near the town of Rennie, which lies on the main highway between Winnipeg and Kenora, about 90 miles east of Winnipeg, Manitoba.

Five permanent study plots were established in three types of tamarack bogs. All plots were square, encompassing 4.9 acres, and permanent trap positions were marked grid fashion on the plots. Eight lines were cut through each plot with a one-chain (66 feet) interval between and within lines giving an 8×8 grid or 64 trapping stations. The habitats varied according to the following descriptions.

Plot 1.—This plot was situated in a mixed stand of tamarack and black spruce approximately 30 to 40 feet in height. Crown closure as measured by the "moosehorn" technique (Robinson, 1947) was about 50 per cent. The stand was stocked with some 312 tamarack stems per acre, *Larix laricina* (DuRoi) K. Koch, with an average d.b.h. (diameter breast height) of 5.8 inches, and 156 black spruce per acre, *Picea mariana* (Mill.) B.S.P., with an average d.b.h. of 5.4 inches. Sphagnum moss occupied about 36 per cent of the forest floor, and Labrador tea, *Ledum groenlandicum* Oeder, comprised about 26 per cent of the ground cover. Water occupied about 7 per cent of the ground surface. The east side of the plot was parallel to and about 20 feet from the Central Whiteshell Road and a small rock outcrop encroached slightly on to the southwest corner.

Plot 2.—This plot was situated in a mixed stand of tamarack and black spruce ranging from 12 to 18 feet in height. Crown closure was about 15 per cent. Tamarack comprised about 187 stems per acre with an average d.b.h. of 2.2 inches, while black spruce comprised about 128 stems averaging 3.6 inches

d.b.h. Sphagnum moss occupied about 21 per cent of the forest floor. Grasses and sedges (23 per cent) and Labrador tea (17 per cent) were the chief components of the ground cover. Surface water occupied about 9 per cent. Pitcher plants, *Sarracenia purpurea* L. were very noticeable and *Andromeda glaucophylla* Link, and *Vaccinium* spp. were common. Although the surface water on this plot was comparable to that on Plot 1, the water table was much closer to the surface. Since the trees were rather small, the site was quite open and resembled a meadow type habitat.

Plot 2A.—This plot was 10 chains west of Plot 2. It was very similar to Plot 2, but a rock outcrop occurred just off the northeast corner.

Plot 3.—This was an extensive, pure tamarack stand with trees about 40 feet in height, with about 260 stems per acre averaging 5.1 inches d.b.h. Crown closure was 55 per cent. Sphagnum moss occupied about 17 per cent of the forest floor and grasses and sedges (about 20 per cent) were the chief components of the ground cover. Surface water occupied about 29 per cent when the plot was established in 1952. In the fall of 1953 a drainage ditch was cut through the stand close to the northern boundary of the plot, and in 1954 no surface water remained. By 1955 the water table had fallen to about 26 inches below the surface.

Plot 3A. This plot was situated 5 chains south of the preceding plot and was similar to it. It contained 283 tamarack stems per acre averaging about 35 feet in height with an average d.b.h. of 4.9 inches. Surface water occupied about 36 per cent before drainage, and similar effects to those on Plot 3 occurred after drainage.

FIELD TECHNIQUES

The fundamental problem of this project was to determine the populations of the various species of small mammals frequenting the tamarack bogs of the study area. An estimate of the populations of mammals per unit area was desirable in order to gain an understanding of the predatory effects of small mammals on larch sawfly cocoons and to relate this to life table studies of the prey insect. Live traps were used so that the mammal fauna on the plot would not be disturbed excessively.

Early phases of the work utilized the Sherman live trap and the resultant captures were marked with ear punctures using a modification of the numbering system outlined by Burt (1940). Later, fingerling tags were used for marking. The mortality of shrews, however, was high even when the traps were examined at hourly intervals. On Plot 3, where high populations of these animals were anticipated, permanent tumble-in traps were set out as described in an earlier paper (1955*a*). Living animals were handled by releasing them into plastic food bags from which the pertinent information such as species, sex and age could readily be seen and recorded with minimum discomfort to the animal. They were then marked and set free.

In addition to the live-trapping experiments, household snap-back traps were tested to determine whether these could be used to derive rapid and accurate population estimates. The technique was tested in stands large enough to accommodate both trapping programs and at a distance from which no interference was caused to the permanent live-trapping experiments.

In earlier experiments, all traps, except those used in tests on bait effectiveness, were baited with a mixture of oatmeal and peanut butter. Where high populations of shrews were to be expected, live traps were baited with oatmeal and peanut butter, but in 1955

this was supplemented with 2-gram portions of canned dog food with 2 cc. of intravenous Chlorpromazine (Largactil, supplied through the Poulenc Co. Ltd., Montreal) thoroughly mixed into one pound of dog food. The use of Largactil was suggested by Mr. R. Standfield, Ontario Department of Lands and Forests. The drug is a depressant to the central and peripheral nervous systems and appears to reduce shrew mortality through its calming effect. Nesting material consisted of dried sphagnum moss, since it was found that shrews often became entangled in cotton used for this purpose.

BAIT EFFECTIVENESS AND SURVIVAL IN TRAPS

During live-trapping in early July on Plot 2, two lines of traps (16 traps) were baited with oatmeal and peanut butter and two lines with old cheese. Three nights of trapping captured six *Microtus* and three *Clethrionomys* using the peanut butter and oatmeal, while not a single animal was captured in the traps baited with old cheese.

Before the first trapping period on Plot 3A, each of the three types of bait was used on two lines of snap-back traps with each bait type being separated by an intervening line. This arrangement was maintained for three nights, giving 48 trap nights for each bait. Table 1 shows a definite preference for peanut butter and oatmeal.

The degree of survival of captives varied with the trapping techniques. Survival in *C. gapperi* and *M. pennsylvanicus* when Sherman traps were visited once daily was never lower than 80 per cent. When traps were visited twice daily, survival of these species increased to 95 per cent. Of the shrews, *B. brevicauda* exhibited 30 per cent survival, *S. arcticus* 10 per cent, and *S. cinereus* 0 per cent in Sherman traps visited twice daily. When Sherman traps were visited at hourly intervals, survival of *S. arcticus* increased to 60 per cent and *S. cinereus* to 30 per cent.

The use of tumble-in traps, which were visited twice daily, aided in survival of shrews. The survival of *S. arcticus* under these conditions was 90 per cent, and *S. cinereus* 50 per cent. The addition of a small portion of Chlorpromazine in the bait further increased survival of *S. arcticus* to 95 per cent, and *S. cinereus* to 85 per cent, and the occurrence of live multiple captures became conspicuous.

TABLE 1. — *The effect of bait in trapping small mammals*

SPECIES	NUMBER OF CAPTURES IN 48 TRAP NIGHTS		
	Oatmeal and peanut butter	Bacon rind	Old cheese
Sorex cinereus	10	4	0
S. arcticus	2	0	0
*S. fumeus**	1	0	0
Clethrionomys gapperi	1	1	0
Microtus pennsylvanicus	2	1	0
Totals	16	6	0

* This is a questionable record based upon one specimen which was lost before it could be identified.

HOME RANGE

The concept of home range is important where estimates of populations of mammals per unit area are required. The problem and its implications have been stated by Hayne (1949), Burt (1940), Stickel (1946, 1954), Blair (1941) and a number of others. It will suffice to point out that, when trapping is carried out on small areas, animals whose ranges border on the plot but who reside chiefly off the plot will be captured in the outside lines. Hence if it

is assumed that the area encompassed by the traps is the total area trapped, a sizeable error ensues. This error may be corrected by including a boundary strip, the width of which is the cruising radius of the species concerned, as part of the area trapped. It has been suggested that the home range of a species may vary with age, sex, season, and population density. No such variations were noted during the course of the present experiment, hence the home ranges of each species were grouped for all ages, sexes, and trapping periods for each plot. Ranges were then calculated using the summation of "trap units" as proposed by Blair (1940). In the one-chain grid used in these experiments, the trapping unit is one tenth of an acre. Where an animal was captured consistently in outside lines, or less than seven times, it was excluded from home range calculations. Where an individual range was obviously extended beyond the regular trapping area, the complete range was established by supplementary trapping in the area adjacent to the plot. When an animal was captured three nights consecutively in the same trap, that trap was closed in order to cause the animal to disclose a larger portion of its range. Table 2 lists the ranges of the various species on the plots studied, and the effective trapping area of each species for the plot size used in this study.

The average cruising radius of *C. gapperi* on Plot 1 was 13.5 feet greater than that on Plot 2, and the value of t is 8.8, showing the difference is significant at the 1 per cent level. The author has captured this species frequently in small trees but seldom in tall trees. The difference in range may therefore be a reflection of habitat utilization, viz., on Plot 1 all foraging is being carried out on the ground but excursions into the smaller trees on Plot 2 may be limiting the horizontal component of the range.

TABLE 2. — *Home ranges of the small mammal species*

SPECIES	PLOT	CRUISING RADIUS IN FEET	S.D.	NUMBER OF MEASUREMENTS	EFFECTIVE TRAPPING AREA
S. cinereus	1	139	(range 134-144)	3	
	3	138	(range 129-148)	5	12.2 acres
S. arcticus	3	146	±14	11	12.3 acres
C. gapperi	1	89	±14	11	9.4 acres
	2	76	±10	21	8.7 acres
M. pennsylvanicus	2	73	±19	12	8.5 acres

POPULATIONS

Boundary Effects in Population Assessment.—Once a measure of the cruising radius has been made, this may be added to the area encompassed by the traps to give the effective trapping area as shown in Table 2. When a population determination has been made, this may then be divided by the effective trapping area to give a population figure in terms of animals per unit area. Since all plots were of the same size, the cruising radius for each species, as determined on any one plot, was used for all remaining plots except that of *C. gapperi*, which was shown to vary significantly with habitat.

It should be noted again that a roadway ran parallel to the eastern boundary of Plot 1 at a distance of about twenty feet and that a rock outcrop arose just off the northeastern edge of Plot 2A. These occurred through the necessity of fitting a plot of appropriate size into the space available. It might be argued that these constitute barriers over which animals will not travel. The ranges of five *C. gapperi* were determined on Plot 1 and although these were not used in calculating the home range of the species, it is apparent (Fig. 1) that these animals are utilizing both sides of the road "barrier" as a portion of their range. The average cruising radius is 107 feet when the road is included as a portion of the range and 91

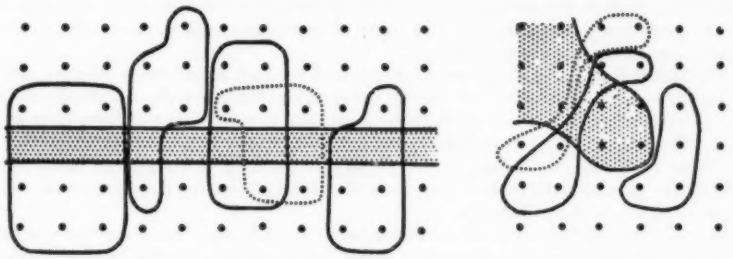

FIG. 1. – The influence of a road "barrier" on the range of *C. gapperi* (left), and a rock outcrop "barrier" on the range of *M. pennsylvanicus* (right). Dots indicate trap locations at 66-foot intervals. "Barriers" are shown in light stippling.

feet when the road is excluded. The latter is more in keeping with previous determinations. Similarly, three ranges were determined for *M. pennsylvanicus* (on Plot 2A) which occupied a portion of a rock ridge as shown in Fig. 1. The cruising radius for *M. pennsylvanicus* is 98 feet, including the rock outcrop or 74 feet excluding the barrier. On these limited data, it is apparent that these species may utilize portions of their range on either side of a "barrier" such as a roadway or a low rock outcrop, but that the area of the "barrier" itself is "vacuum" territory in home range establishment. Hence the author has included a boundary strip even where such "barriers" occur.

Population Assessment Using the "Lincoln Index" Technique.—Where the population of mammals is low, it may be determined directly by trapping and releasing until only marked animals are captured. However, where large numbers of a species are being taken it is often impractical to continue trapping until only marked animals are being captured. Perhaps the most useful technique advanced to overcome this difficulty is the calculation of population density by means of the "Lincoln Index." This makes use of the formula $T = m/(x/n)$ where T is the total population, m is the number originally marked, n is the sample size, and x is the marked animals in the sample. It has been pointed out by Ricker (1948) that this equation is valid only when the following conditions are fulfilled. There must be equal mortality in marked and unmarked animals; the marked animals must retain their marks; all animals must be randomly mixed *or* the distribution of sampling effort must be proportional to the number of animals in various areas of the study plot; and, natural changes in the population should be negligible during the sample period. Adams (1951) has further suggested that the technique is open to statistical errors and has published tests that might be applied in order to determine the confidence limits of the data. The Lincoln Index has been applied to portions of the data obtained during the present study and it was found that, at the 95 per cent confidence interval, the limits of the population range were excessively wide. Even

TABLE 3. – *Lincoln Index for C. gapperi on Plot 2, August 1952*

DETERMINATION	m	x/n	T	APPROXIMATE CONFIDENCE INTERVALS		
				95%	90%	80%
First	2	.11	19	7-67	6-67	7-50
Second	16	.50	32	24-49	24-47	26-43
Third	20	.53	38	29-56	29-53	31-48
Fourth	28	.46	37	32-49	33-46	33-44
Accumulation	28	.46	61	51-85	48-80	51-76
Final 3	28	.59	47	38-64	39-62	41-58

when all or parts of the data had been combined, little confidence could be expected. This was perhaps due to the rather small number of individuals with which students of small mammal populations are concerned.

The author feels that perhaps we are working at too high a confidence level for our limited data, and that we may have to use less stringent confidence bands. Admittedly this procedure would increase the risk of accepting more false hypotheses, i.e., of obtaining significant differences when no true differences exist, but at the same time it would increase the chances of detecting differences in population densities, or differences using various techniques. Accordingly, Table 3 lists a sample Lincoln Index for *C. gapperi* with various calculations of confidence intervals.

Since Lincoln Indices may be calculated for each trap night excepting the first, there arises the problem of selecting the most accurate determination. Usually the first determination may be discarded on the ground that only a few marked animals exist, and hence the probability of error is high. In many cases the final determination is most accurate since the confidence interval decreases on successive determinations. However, G. B. Oakland (personal communication) suggested a grouping of the final three determinations in order to guard against an inaccurate final determination.

In addition to the statistical errors that might arise from injudicious use of the Lincoln Index, there may also be errors arising from the trapping behavior of the species under investigation. Tanaka (1952) and others have shown that in some cases marked animals return more readily to traps than do unmarked animals. If this is true the Lincoln Index would not give a true estimate of the population. The reliability of the Lincoln Index as a measure of population was tested by continuing some of the trapping periods until only marked animals were taken, which took about 15 trappings for moderate populations. The results, as shown in Table 4, are consistent with the Lincoln Index determination, or within its confidence interval at the approximate 95 per cent level. It is felt that data grouping, and the use of "tumble-in" traps in the case of shrews is the redeeming feature in the success of the Lincoln Index in the present experiments.

TABLE 4. — *A comparison of Lincoln Indices and total animals captured*

SPECIES (Adults only)	PLOT	DATE	LINCOLN INDEX	TOTAL CAPTURED
C. gapperi	1	July, 1952	26(22 - 33)	29
	2	August, 1952	47(40 - 56)	43
	1	August, 1955	36(33 - 45)	36
M. pennsylvanicus	2	July, 1952	31(26 - 48)	36
	2	July, 1952	28(17 - 35)	23
S. cinereus	2	September, 1953	13(11 - 18)	16
S. arcticus	3	July, 1954	24(20 - 36)	28
	3	August, 1954	36(32 - 45)	33
	3	July, 1955	26(22 - 33)	27
	3	August, 1955	47(41 - 58)	52
	3	September, 1955	41(31 - 47)	40

Population Appraisal With Snap-back Traps.—In certain instances it would be of advantage to dispense with live traps in favour of snap-back traps, which are quickly set and easily carried. Tests were carried out in which populations were assessed by live traps on Plots 2 and 3, and with snap-back traps on Plots 2A and 3A. In addition, standard trap lines consisting of 50 snap-back traps (operated for three nights) were set on either side of the plot series, at a distance such that no inter-plot effects might be expected. To convert these

TABLE 5. — *Comparison of small mammal populations per acre using three trapping techniques*

DATE	TECHNIQUE	PLOT	*C. gapperi*	*M. pennsylvanicus*	*S. cinereus*	*S. arcticus*
1953						
Sept.	A	2	1.09	1.29	1.89	—
	B	2A	1.09	1.17	3.31	—
	C	2*	1.34	1.38	2.42	—
1954						
June	A	2	—	1.06	.16	—
	B	2A	—	.35	—	—
	C	2*	—	.47	—	—
July	A	3	—	—	1.87	2.05
	B	3A	—	—	1.97	1.97
	C	3*	—	—	2.00	1.65
Aug.	A	2A	—	4.41	.16	—
	B	2A	—	4.29	.16	—
	C	2A*	—	4.82	—	—
Sept.	A	3	.58	.59	2.23	2.98
	B	3A	.53	.38	2.18	2.95
	C	3*	.36	.44	3.00	3.16
1955						
June	A	2A	—	2.00	.33	—
	B	2A	—	1.06	.08	—
Aug.	A	2A	—	4.94	.90	—
	B	2A	—	5.40	.74	—

A—live traps on grid; B—snap-backs on grid; C—snap-backs on standard line; *—line in vicinity of permanent plot.

to a common unit, the cruising radius of each species was then added to the trapping area. The results of this experiment are shown in Table 5. In general, the populations are similar regardless of the trapping method employed.

It will be noted, however, in the Plot 2 series of June 1954, that lower populations were indicated by snap-back traps. This may be attributable to population variation or to a real difference in trap behavior. In 1955, Plot 2A was first live-trapped in June and then snap-back trapped. A second trial was run in August on the same plot. Apparently the population in early summer is less susceptible to snap-back trapping than it is in the late summer periods, and in order to describe more accurately a spring or early summer population it might be advisable to double determinations made by snap-back trapping. In the earlier part of the year, on an open plot such as the Plot 2 type, the ground cover is sparse. Animals may be reluctant to expose themselves to the open feeding sites of snap-back traps, but may be willing to enter the closed sites of the live traps. As the summer advances and the ground cover becomes more dense, the snap-back traps may present a more secluded and hence more appealing feeding site and tend to equalize any difference in the reaction of the animals to the two types of traps.

In conjunction with an entomological experiment it was necessary to remove the entire small mammal population from Plot 3A in the midsummer of 1952 and to maintain a mammal-free condition until the following June. It is not known conclusively if it is possible

to remove the entire small mammal complement from an area. Saunderson (1950) found that during an extended trapping period of over 40 consecutive days, considerable numbers of small mammals were still being trapped. However, in the author's experiment beginning in July 1952, animals were captured in snap-back traps up to the sixth day, after which no further animals were captured. After an interval of two weeks, no animals were captured on the body of the plot, but a few were taken in the two outside lines. Trapping was resumed on this plot in early May of 1953 in order to keep the mammals from the plot. The results of the experiment are summarized in Fig. 2, and these strongly suggest that saturation trapping is possible.

The success of this experiment was probably dependent upon the habitat type and hence the species complement of the plot. The habitat was of such a nature during the course of the experiment that only *S. cinereus* was in abundance. The habitat was probably marginal for the Microtines. The lower shrew population (2.21 per acre) and presumably the lower powers of reproduction of these animals were probably important factors in the efficiency of trap removal. Undoubtedly much more difficulty would have been experienced had higher populations or more rodent species been prevalent during the experiment.

From these experiments it may be concluded that, where a rapid census of small mammals is required, a snap-back trapping program will yield reliable results in late summer, but in early summer such determinations should be treated with caution. Where the mammal fauna is to be studied over long periods, however, snap-back traps should be avoided wherever possible, since an extensive removal, especially of shrews, may have severe and prolonged effects on the population.

Small Mammal Populations in Tamarack Bogs.—The small mammal fauna of the tamarack bogs under investigation was comprised of four main species, namely, S. *cinereus*, S. *arcticus*, C. *gapperi* and M. *pennsylvanicus*. The populations of these species are presented in Fig. 3. Marked differences in species and abundance occurred throughout the three plots and these were probably reflections of the habitat, along with the annual fluctuations of the population. The dominance of C. *gapperi* on Plot 1 was possibly related to two factors of the environment, the dense crown closure and the relatively dry floor. Plot 2 was probably most suitable to M. *pennsylvanicus* because of conditions diametrically opposite to those on Plot 1, namely an open site and a wet floor. Plot 3 was extremely wet during the earlier

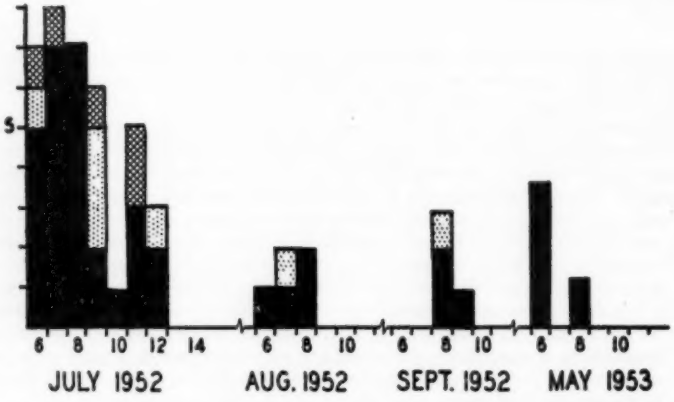

FIG. 2—Trap removal of small mammals on Plot 3A. Ordinate expressed in animals removed from the plot. The dark areas represent S. *cinereus*, the hatched areas C. *gapperi*, and the stippled M. *pennsylvanicus*.

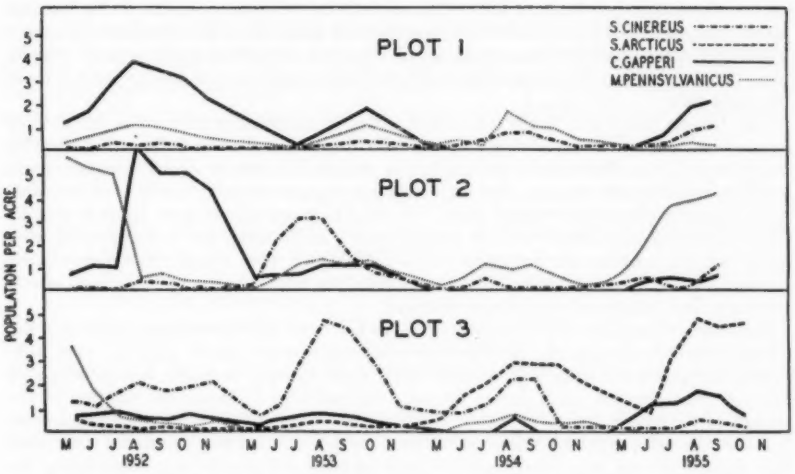
PLOT 1
PLOT 2
PLOT 3
S.CINEREUS
S.ARCTICUS
C.GAPPERI
M.PENNSYLVANICUS
POPULATION PER ACRE
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1952
1953
1954
1955

FIG. 3. — Four-year population trends of the major species inhabiting tamarack bogs of eastern Manitoba.

part of the study but had a dense crown closure, and these conditions seemed to favor *S. cinereus*. Later, as the plot was drained and became quite dry on the floor, *S. arcticus* succeeded *S. cinereus* as the dominant species. A second possible effect of drainage was the increase in the population of *C. gapperi* on this plot. It appears that this plot will culminate in conditions resembling those on Plot 1, and that the appearance of *S. arcticus* is a transient phase in the succession from a wet to a dry bog.

The sharp decline in the population of *M. pennsylvanicus*, as shown in August of 1952 (Fig. 3), the low numbers of *C. gapperi* in 1953, and the absence of this species in the trapping records of 1954, except on Plot 3, suggest "population crashes." Although any concrete statement regarding annual population cycles would be premature at this time, it appears that the low point in the current cycles of these two species was established in this area, and that the cycles in the two forms are not strictly in phase with each other.

In addition to the dominant species previously mentioned, certain other species were recorded on the various plots in low numbers. *Peromyscus maniculatus* was taken occasionally on Plot 2 in 1952 and 1953 (.2 and .33 per acre respectively) and rather consistently on Plot 1 in the easterly two chains. *Zapus hudsonicus* has also been recorded, one specimen having been taken near the rock outcrop on Plot 2, and three specimens at the roadside traps on Plot 1. During the 1954 season, one *Synaptomys cooperi* was taken on Plot 1, and three on Plot 3; in the 1955 trapping operations, one was marked on Plot 1 and subsequently recaptured at seven different locations. At the same time, one specimen of *Sorex palustris* was marked and recaptured at two locations. Early in 1952, one specimen of *Blarina brevicauda* was taken near Plot 3. No further records of this species were made until August 1955 when nine specimens were captured on Plot 3 and nine on Plot 1. Several weasels, *Mustela erminea*, were taken on each plot and rare captures of *Tamias striatus*, *Eutamias minimus*, and *Tamiasciurus hudsonicus* have been recorded on Plots 1 and 2 .

DISCUSSION

It has been pointed out by Morris (1955) that in order to study the relationships of small mammals to forest insects, essentially a problem of population dynamics, it is desirable to

express populations per unit area rather than as an index of relative abundance. He has suggested that possibly all methods used to census small mammals will have sources of errors. This paper assesses some of the errors one encounters in evaluating small mammal populations, and presents data on some of the small mammals encountered in the tamarack bogs of the study area.

The Lincoln Index was closely scrutinized to test its accuracy as a means of determining populations, and it was found that if errors do occur, due to the trap habits of the species under investigation, they may be masked by the statistical limitations of the technique itself. Students in community ecology, therefore, need not concern themselves with correction factors, at least for the species treated herein. In order to guard against gross errors in population estimates, it is advisable to make some grouping of the data, and it is suggested arbitrarily that the last three determinations be used (Table 3). Less stringent confidence bands are also suggested in order to test hypotheses regarding small mammal populations, especially since large samples are seldom encountered.

Snap-back traps were used in conjunction with live traps and the resultant population determinations were compared. No significant differences were found using the two techniques, except for the snap-back determinations made in early summer. It was suggested that the sparse ground cover during the early summer may influence the reaction of the animals to the type of trap being used. Caution should be exerted in using snap-back traps to make population estimates before midsummer, for it was found that population determinations using live-traps were about twice as large as those using snap-back traps during the month of June. Later in the summer, however, no significant differences were found using the two types of traps. Snap-back traps should be avoided, however, where prolonged studies in a restricted area are contemplated.

In determining absolute populations, a boundary strip equal to the cruising radius of the species concerned should be added to the area encompassed by the traps. Slight errors may be encountered if a change in habitat occurs and the ranges of the experimental animals are not reassessed. A 6 per cent error has been shown for *C. gapperi*, which was the only species that occurred in sufficient numbers in two types of habitat to determine ranges. The magnitude of the error is not great, and hence students unable to determine the ranges of their experimental animal may stand little chance of erring if the plot under study is reasonably large and the boundary strip, as determined by some other authority, is used, especially if the habitats are somewhat similar. The range of each species did not appear to be influenced by season, population density, or sex.

SUMMARY

1. A mixture of oatmeal and peanut butter was the most effective bait used. This was especially true when supplemented with canned dog food mixed with Chlorpromazine to decrease shrew mortality.

2. The cruising radious of *Sorex cinereus* was 139 feet, *S. arcticus* 146 feet, *Microtus pennsylvanicus* 73 feet, and *Clethrionomys gapperi* 89 feet in a stand of tall trees and 76 feet in a stand of small trees. Portions of the ranges of several *C. gapperi* and *M. pennsylvanicus* occurred on both sides of a "barrier," which appeared to be disregarded in the spatial relationships of range establishment.

3. The Lincoln Index is a reliable means of assessing the populations of the species studied herein.

4. Snap-back traps give a reliable population estimate except in early summer. Their use is open to question in long-term studies.

5. *M. pennsylvanicus* was the dominant species in open stands and *C. gap-*

peri in closed stands, except those in which the water table was high. *S. cinereus* was found chiefly in closed, wet stands and to a lesser extent in open, wet stands. *S. arcticus* was found only in a changing site progressing from wet to dry. *Peromyscus maniculatus, Zapus hudsonius, Synaptomys cooperi, Sorex palustris,* and *Blarina brevicauda* were taken occasionally. Several specimens of squirrels, chipmunks and weasels were also captured on the plots.

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NOTES ON THE SMALL MAMMALS OF CHURCHILL, MANITOBA

By Donald A. Smith and J. Bristol Foster

The Churchill area lies in the important zone of transition between the boreal forest which lies to the south and west, and the tundra which extends to the north. This region is inhabited by a large and varied fauna with both forest and tundra forms represented. Among the mammals, certain boreal forest species such as the squirrel, *Tamiasciurus hudsonicus;* the voles, *Clethrionomys gapperi, Phenacomys intermedius* and *Synaptomys borealis;* and the jumping-mouse, *Zapus hudsonius,* reach the northern limit of their range up the west coast of Hudson Bay in this region. Here too, tundra species such as the hare, *Lepus arcticus,* the lemmings, *Lemmus trimucronatus* and *Dicrostonyx groenlandicus;* and the fox, *Alopex lagopus,* reach or near their southern distribution limit.

The first comprehensive account of the mammals of Churchill is by Preble (1902) who cites most of the scattered early references to mammals, and who reports on collections made there during three weeks in August, 1900. This contribution is still the most useful report on this region, especially with respect to the larger mammals. Workers who have subsequently added to our knowledge of Churchill mammals include: Breckenridge (1936), who collected a few specimens in 1933; Shelford and Twomey (1941), who were concerned primarily with tundra communities; Shelford (1943), who discusses lemming population changes; and Quay (1955), who records brief notes on three species of mammals collected in 1953. In addition, Rand (1948) reports on the mammals of the Herb Lake-Flin Flon area of west-central Manitoba, and appears to be the only other author who deals with the mammals of any part of the entire northern half of the province of Manitoba.

During recent summers, the authors had the opportunity to study mammals in the Churchill area while engaged in biological field investigations of a different nature than those reported herein. Smith carried out field studies from May 27 to August 31 in 1951, and from May 25 to September 17 in 1952, while stationed at the Defense Research Northern Laboratory (D.R.N.L.) at Churchill, as a summer employee of the Defense Research Board of Canada. Foster was at Churchill in a similar capacity from May 16 to September 7 in 1954. The following year, Foster and Robert M. Bateman were at Churchill from June 13 to October 1 to study the life history and ecology of phenacomys voles. The latter investigation was financed by a grant from the National Research Council of Canada to Dr. R. L. Peterson of the Royal Ontario Museum of Zoology and Paleontology (R.O.M.Z.P.), Toronto. Facilities for research were again provided by D.R.N.L.

The present account contains the results of field and laboratory studies carried out in the limited amount of spare time available in 1951, 1952, and 1954, together with a resumé of Foster's full-time investigations in 1955. Our data are supplemented by a few unpublished records from other workers and by a

summary of published data on small mammals from northern Manitoba.

Mr. H. L. Gunderson of the Minnesota Museum of Natural History visited Churchill in 1953, and has generously allowed us to quote some of his data. We have also examined two small collections of Churchill mammals recently received by the Royal Ontario Museum. One collection was made in 1949 by Mrs. A. F. MacIvor of Churchill, and the other by A. G. Edmund of Toronto, Ontario, in 1950.

Grateful acknowledgment is made to the above institutions and individuals, and also to the Royal Canadian Air Force, and to W. E. Beckel, T. P. Copps, C. A. Barlow and Mrs. M. G. Arsenault of D.R.N.L., for their interest and assistance which greatly facilitated these studies.

DESCRIPTION OF STUDY AREAS AND METHODS

The topography of the forest-tundra transition zone that surrounds Churchill in which our mammal studies were undertaken is varied. During the four summers we were at Churchill, field work (mainly trapping) was carried out in areas representative of all important types of terrain in this region. The sequence of these main types may be briefly described as follows. A coastal rock ridge (quartzite and limestone) quickly sinks to the overall flatness of the low tundra and thence to the more or less continuous spruce-larch forest which begins several miles inland. A few scattered woods lie sheltered in the lee of the rock ridge. Along part of the coast, a grassy, sand beach extends from the intertidal zone to the rock ridge.

Fig. 1 shows the extent of the main cover types briefly described below and the locations of our major trapping stations within them.

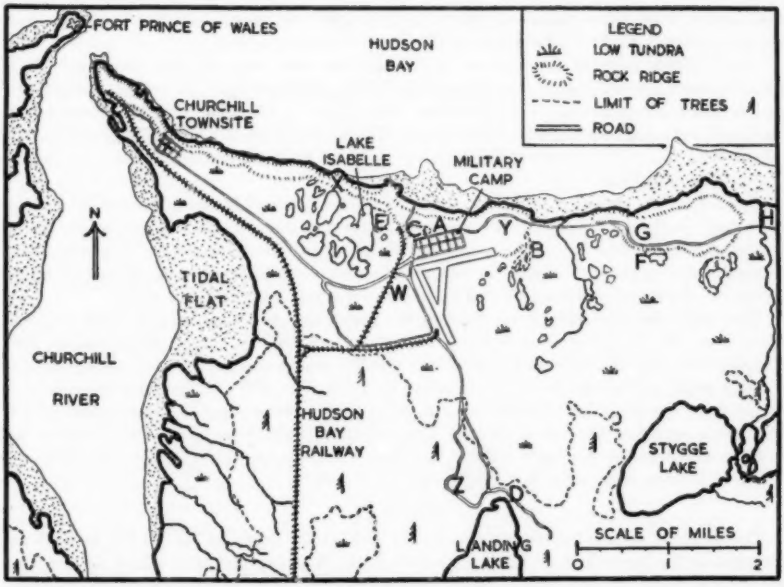

FIG. 1.—Topographic map of the Churchill region, showing the locations of major trapping stations A to H and W to Z.

Rock Ridge.–The vegetation varies from but a few crustose lichens on exposed boulders to thick cushions of lichen-heath climax tundra. The dominant lichens are *Cladonia alpestris, C. rangiferina, Cetraria nivalis* and *Alectoria ochroleuca.* The dominant heaths are *Arctostaphylos* spp., *Loiseleuria procumbens, Vaccinium* spp., *Andromeda polifolia, Rhododendron lapponicum* and *Ledum* spp., while another common plant is *Empetrum nigrum.* Dwarf birches (*Betula glandulosa*), willows (*Salix* spp.) and a few stunted white spruces (*Picea glauca*) grow in sheltered spots. *Trapping stations*: X, Y (1951); A (1954) and G (1955). In addition, Gunderson set a few traps here in 1953.

Low Tundra.–This variable category includes all low, flat country without trees. Much of the low tundra is made up of rather wet areas whose abundant plants are: sedges (*Carex* spp. and *Scirpus caespitosa*), grasses (*Poa pratensis, Elymus arenarius* and *Calamagrostis neglecta*), as well as *Triglochin* spp., *Juncus alpinus,* and several mosses. These wet areas are often interspersed with dry hummocks of climax tundra similar to that of the rock ridge, with many shallow ponds, and by clumps of low willows and dwarf birch. *Trapping stations*: W (1951) and H (1955).

Open Spruce-Larch Forest.–Strictly the "typical" boreal forest lies many miles inland. However, this category includes the most heavily forested parts of the Churchill region. It is made up of extensive areas of usually moist, boreal forest-tundra transition zone where scattered, stunted spruces and larches grow in a dense, hummocky ground cover of fruticose lichens, mosses, heaths (*Ledum* spp. dominant), dwarf birch and willows. Num. erous sedges and grasses grow in and around the many ponds. *Trapping stations* were: Z (1952), D (1954), and several dry areas of the forest about 10 miles east of the camp (1955). In 1953 Gunderson trapped near areas Z and D.

Sheltered Woods.–Several isolated pockets of trees were growing in the lee of the rock ridge along the coast. These woods were generally quite dry and open; but the stunted spruce trees occasionally grew in dense stands. There was a scanty ground cover of lichens and heaths, with some clumps of willows and dwarf birch especially around ponds. *Trapping stations*: B, C, E, F (1954 and 1955).

Beach.–Drier parts of the sand or gravel beaches were covered with dense patches of coarse grass (*Elymus* spp.) and *Arenaria peploides,* while damper parts had *Senecio congestus* and *Matricaria inodora* in profusion. On higher beach areas, a later xeroseral stage has been attained, and *Dryas integrifolia* was the dominant plant. No trapping was carried out on the beaches but many observations and hand captures of microtines were made here in 1952, 1954, and 1955.

Our field work consisted primarily of setting lines or plots of Museum Special break-back traps and Sherman live-traps. The chance of survival of trapped animals was markedly enhanced when the live-traps contained large wads of non-absorbent cotton to provide vital insulation during the raw nights. In general, traps were set in runways, at holes and beside rocks, tree bases and fallen trees, and they were examined once or twice daily.

The upper half of Table 1 summarizes the particulars of trapping from 1951 to 1955. Most of our trapping was done in forested areas and on the rock ridge. All of Smith's 1952 trapping was carried out in a one-acre plot (area Z), which was delimited on three sides by a sedgy pond and on the fourth by a road. In 1955, over 4500 of the Sherman live-trap-nights were compiled in 71 nights on a three-acre plot within area C. Here, most of 100 traps were unmoved for over a month. The remaining 1955 trapping was done within the triangle whose apices are Lake Isabelle, Landing Lake, and a point 12 miles east of camp. Break-back traps were usually moved every three days.

RESULTS

The numbers of small mammals trapped in each of the summers from 1951 to 1955 are recorded in the lower half of Table 1. Although the trapping procedures and the time devoted to trapping differed considerably from summer to summer, fluctuations in the relative numbers of small mammals in the several years can be detected in these data supplemented by general observations. Nearly all mammals trapped or observed were microtines;

hence, most of the following applies to this group.

The lowest numbers of microtines in the period under study occurred in 1951 when Smith observed and caught only three lemmings or voles after extensive searching. By the summer of 1952, a dramatic increase in their numbers had taken place. Microtines, especially meadow voles, were conspicuous and Smith saw many in areas where none were seen in 1951 in spite of numerous visits.

Observations made by Copps (personal communication) during the autumn of 1952 and the following winter indicate that the abundance of small mammals continued throughout that period. In mid-September, Copps saw many voles, their runways and droppings. He reported much rodent damage to grasses, sedges and shrubs in the Landing Lake area. He observed several large yellow mushrooms with nibbled edges and with vole droppings upon and under them. During early November, he reported that "mice" were still extremely plentiful.

Copps and Barlow of D.R.N.L. reported that there were still many voles and now many lemmings in the Churchill region during the summer of 1953.

In May, 1954, Foster observed many snow drifts riddled with rodent tunnels with piles of droppings at their entrances. He noted that many willows had been stripped of their bark, both near Churchill and in the forest 20 miles to the south. Trapping showed that voles were numerous during the summer and this situation continued in the fall, according to Copps.

Mr. A. F. MacIvor, a trapper in Churchill, reported that in 25 years travelling through the forest south of Churchill, he had never seen the bushes so badly stripped of their bark as he had the spring of 1955. Vole populations remained high for the fourth consecutive summer. In almost all new trapping sites, at least one vole was caught for every five traps set, and frequently the ratio was one in three.

Our results may be compared with the conclusion of Shelford (1943) that at Churchill, the peak in vole numbers preceded the peak in lemming numbers by one year. As trapping was not carried out in a uniform manner from 1951 to 1955, our results in Table 1 are not

TABLE 1. — *Extent of trapping and its results*

	1951	1952	1953	1954	1955*
Collectors	Smith	Smith	Gunderson	Foster	Foster & Bateman
Dates of trapping	June 14-July 14	June 12-Sept 3	June 17-July 4	May 20-Sept. 5	June 14-Sept. 30
Trap-nights: break-back traps	260	2427	575	190	2200
live traps	350	—	—	2110	6500
Total trap-nights for year	610	2427	575	2300	8700
Catch: (by species)					
Sorex cinereus		1			3
Mustela erminea					3
Tamiasciurus hudsonicus					1
Clethrionomys gapperi		10	6	240	439
Phenacomys intermedius		2	6	68	192
Microtus pennsylvanicus		60	6	17	44
Synaptomys borealis		3		6	
Dicrostonyx groenlandicus	4			10	5
Zapus hudsonius		5			
Total catch	4	81	18	341	687

* Many recaptures of microtines are included in catch data for 1955.

sufficiently comparable to determine accurately when *peak* populations occurred. However, the present trapping results and field observations at least partially support Shelford's statement. Voles became common in 1952, while lemmings did so in 1953 and probably attained their peak then. Vole numbers were still high in 1955 while lemming numbers decreased in 1954 and 1955. It is evident that, as well as commencing one year earlier than the "high" for lemmings, the high vole population continued long after the onset of the decline in lemming numbers.

The relative numbers of birds of prey observed and the numbers of their nests found in the Churchill region in the summers from 1951 to 1955 apparently followed the trends for microtine populations, as has been noted earlier by Taverner and Sutton (1934) and by Shelford (1943). Among avian predators upon microtines, probably the most important in the Churchill area are rough-legged hawks, short-eared owls and parasitic jaegers. All these predators nested near Churchill when microtines were abundant, and in addition, snowy owls were reported as common winter residents following recent summers when microtine numbers were high.

Direct evidence of predation upon small mammals by avian predators was obtained in several ways. The nests of rough-legged hawks and short-eared owls were consistently decorated with carcasses of microtines. On one occasion, six lemmings and four meadow voles were draped on the branches beside a nest of the former. Skulls of phenacomys, meadow voles and varying lemmings were found to be equally abundant in pellets around a short-eared owl nest found in 1954, and fresh carcasses of two phenacomys and one meadow vole were cached nearby. On four visits to another short-eared owl nest in 1955, Foster found the carcasses of two red-backed voles, three phenacomys, six meadow voles and one juvenile red-backed sandpiper.

Occasionally, short-eared and hawk owls were noted carrying voles, and on two occasions in 1955, when the prey of the latter was recovered, it was found to be a phenacomys. Once in 1955, a parasitic jaeger was seen flying off carrying a vole in a break-back trap in its beak. Presumably this was a regular practice as many traps were stolen on the open tundra.

Owl pellets were collected and examined to ascertain the relative frequency of occurrence of microtines. Several large pellets found on the open tundra in 1951 contained skulls of lemmings only. Large pellets found on the west side of the mouth of the Churchill River in 1955 contained the skulls of one red squirrel, two phenacomys, nine meadow voles and 18 lemmings. Presumably snowy owls were the source of the large pellets.

Many pellets were gathered under trees and occasionally on the tundra in 1955. Most of them probably were from short-eared owls, although some snowy and hawk owl pellets undoubtedly were collected. Most had apparently been deposited during the previous fall and winter, as short-eared owls were never seen near these roosts in the summer, but occasionally were in the fall. Among 243 skulls or parts thereof were skulls of three red-backed voles, 85 phenacomys, 69 meadow voles, and 86 varying lemmings.

Observations of mammalian predators upon small mammals were scarce. A few arctic foxes were noted casually in 1954 and 1955. Copps (personal communication) reported that they were common during the winters from 1952-53 until 1954-55. We noted only two coloured foxes during four summers.

SPECIES ACCOUNTS

Fifteen species of mammals the adult weight of which is less than approximately 1500 grams have been taken in the Churchill area. For a list of the larger mammals that are not treated herein, the reader is referred to Preble's account (1902). To Preble's list and the present one, several other small mammals common throughout the boreal forest or tundra might easily be added if a more intensive survey were carried out. Among hypothetical forms are the shrews *Sorex arcticus* and *Microsorex hoyi;* several bats; the vole *Clethrionomys rutilus;* the mouse *Peromyscus maniculatus;* and possibly the chipmunk *Eutamias minimus* and the flying squirrel *Glaucomys sabrinus.*

The nomenclature herein follows Anderson (1947) for all groups except the microtines,

for which subfamily the more recent revision of Hall and Cockrum (1953) has been followed. Attention is drawn, however, to certain forms for which the present taxonomic treatment seems inadequate.

As many of the specimens trapped or taken by hand by ourselves or by our colleagues at DRNL were examined as time allowed. Standard linear measurements are given to the nearest millimeter as the mean and the extreme range of variation. When available, weights in grams are given in a similar manner. Embryo sizes are the mean CRM (crown-rump measurement) for the litter *in utero*. Testis length was measured as the greatest dimension of one testis in each male, and is stated to the nearest 0.5 mm.

All mammal specimens retained by Smith in 1951 and 1952 are in his personal collection. Foster's 1954 and 1955 specimens have been donated to the Royal Ontario Museum of Zoology and Paleontology. Gunderson's specimens collected in 1953 are in the Minnesota Museum of Natural History.

Some ectoparasites were removed from 1952 and 1955 specimens, and most of the 1952 material was turned over to the Northern Insect Survey, Science Service, Department of Agriculture of Canada.

Sorex cinereus cinereus Kerr. Cinereous shrew.—The R.O.M.Z.P. has recently acquired five Churchill specimens. Three skulls (two "partial") were collected in February-March, 1949, by Mrs. A. F. MacIvor, and two skins with skulls were collected in mid-summer, 1950, by A. G. Edmund.

Smith examined three fresh specimens in early August, 1952, and the skin and skull of one female from area Z are in his collection. In 1955, three were taken by Foster in dry scrubby woods, and all are now in the R.O.M.Z.P.

The average measurements of six individuals (3♂♂, 1♀, and 2 sex undetermined) taken in 1952 and 1955 are: total length, 93 (81–98); tail, 38 (34–40); hind foot 12 (12–13); weight, 3.6 (3.3–4.1).

As the nine skulls examined are similar to those of *S. c. cinereus* from other localities, and as Churchill is within the wide range for *cinereus* given by Anderson (1947), the specimens have been ascribed to this race.

The only previously recorded occurrence of this shrew at Churchill is by Quay (1955) who collected five specimens in 1953. Bryenton found it common in west-central Manitoba in 1945 (Rand, 1948).

Sorex palustris palustris Richardson. Water shrew.—The only known record from Churchill is an alcoholic specimen collected by Mrs. I. H. Smith of Churchill on October 20, 1953. This specimen is at present in the museum of the Department of Zoology, University of Manitoba, Winnipeg, Manitoba, where it was seen and identified by Smith.

Mustela erminea richardsoni Bonaparte. Ermine.—No ermines were observed by the authors until July 1, 1955, when Foster saw a pair at Warkworth Creek, at Mile 499, Hudson Bay Railway. However, none was encountered at Churchill until three were taken in live-traps on July 17, 20, 21 respectively in area C. A fourth was repeatedly seen in the same woods later in the month.

Six specimens from Churchill in the R.O.M.Z.P. were collected in June and July of 1950 by A. G. Edmund. There was no evidence of breeding at this season. Preble (1902) records an immature male taken on the Churchill River, a few miles above Fort Churchill, and another immature from the edge of the barren grounds below Hubbart Point. Breckenridge (1936) and Rand (1948) record *M. erminea* from west-central Manitoba.

Mustela rixosa rixosa (Bangs). Least weasel.—A female taken on July 28, 1950, by A. G. Edmund appears to be the only Churchill record for this little carnivore. The skin and skull are in the R.O.M.Z.P. There was no evidence of breeding. Churchill is within the range for *M. r. rixosa* defined by Anderson (1947) and the specimen has been ascribed to this race.

Preble (1902) did not record this species but he cites a specimen in the U. S. National Museum from Moose Factory and several old references.

Tamiasciurus hudsonicus hudsonicus (Erxleben). Red squirrel.—We saw none at Churchill

from 1951 to 1954, although several of our colleagues reported seeing red squirrels in the larger spruce forests within a few miles south and west of Churchill. However, on June 28, 1955, one was seen in area B, and two days later a specimen was taken in a live-trap a few feet away, and the skin and skull were retained for the R.O.M.Z.P. One skull was found in a large owl pellet on the west side of the mouth of the Churchill River. Preble (1902) saw a specimen taken a few miles up the river, where the animals were said to be fairly abundant.

Clethrionomys gapperi hudsonius Anderson. Red-backed vole.—Smith examined 12 Churchill specimens mostly from area Z in 1952, and retained three skins and skulls. In 1953, Gunderson trapped six individuals near this same area and he retained three specimens. During the summer of 1954, Foster trapped more of this species than of all other mammals combined. Of the 240 trapped, 16 skins and skulls and 36 skulls only were retained. Again in 1955 red-backed voles were very numerous; 439 captures (including 111 recaptures) were made. Thirteen skins and skulls and 71 skulls only were retained.

Among the animals examined, 15 had a dark blackish-brown dorsal stripe and greyer sides than the usual colour phase. On the other hand, two immature individuals taken in September, 1955, were very pale. Their dorsa were dilute Ochraceous Tawny (after Ridgway), and their sides were Pearl Grey. As they were taken on the same rock ridge east of camp, possibly they were from the same stock in which a mutation had occurred.

The average measurements of 64 individuals (35 ♂♂; 29 ♀♀) taken in 1952 and 1954 are: total length, 140 (110–169); tail, 40 (29–51); hind foot, 19.5 (17–21); weight, 27.4 (14.8–43.6).

From counts of embryos and placental scars, the mean litter size was 5.38 (range 4–8) in 21 females whose total lengths varied from 126–155 mm. This mean litter size agrees closely with the value of 5.47 given by Coventry (1937) for *C. g. gapperi* from Ontario. Pregnant females were taken from mid-June until early September.

The 68 males for which breeding data are available may be divided into three groups. There were 49 animals (total lengths 120–161 mm.) with large testes (lengths 9–14 mm.), which were taken from the beginning of trapping until late August, that presumably were in breeding condition. Three large animals (143–146 mm.) taken in September, 1955, and small testes (5 mm.); these probably were adults taken after the breeding season. Sixteen smaller animals (117–134 mm.) with small testes (2–4 mm.), which were taken throughout the summer, apparently were young of the year. These data suggest that males usually reach sexual maturity at a total length of approximately 120–130 mm.

Red-backed voles were numerous in all dense, moist, forested areas investigated. In 1954, they were less common in dry, open woods or grassy woods, and only occasionally were they taken on the tundra. However, in 1955 these voles were also plentiful on the climax tundra on the rock ridge, in *all* types of woods and on willow-covered levees.

Common plants eaten by red-backed voles include: *Vaccinium uliginosum, Arctostaphylos rubra, Shepherdia canadensis, Epilobium angustifolium* and *Salix* spp.

Only rarely were they seen in daylight and never were they encountered on turning over logs or stumps beside which they had holes.

Although more red-backed voles were trapped in 1954 and 1955 than any other species, it is remarkable that only three of 273 skulls found in owl pellets in 1955 were of this species. When handled, red-backed voles were found to be considerably more nervous, wary and agile than other Churchill microtines. These characteristics may partially account for the low incidence of red-backed voles in owl pellets.

Because many red-backed voles were trapped on climax tundra on the rock ridge in 1955, we suspected that some of these animals might be *Clethrionomys rutilus*, which has been taken at Nonala, Manitoba, 80 miles to the north, by Breckenridge (1936). Our Churchill specimens were compared with 39 specimens of *rutilus* from the western Arctic in the R.O.M.Z.P. Many of the Churchill specimens have hairy tails; in this they appear to be intergrades between the hairy-tailed *rutilus* of the tundra and the nearly smooth-tailed *gapperi* of the boreal forest. The 1955 Churchill specimens had significantly longer tails

(about twice as long as the hind feet) than did the *rutilus* material examined (where the tail is about one and one-half times as long as the hind feet). This character, as well as those of the skull (especially the complete post-palatal bridge) of the Churchill red-backed voles was that of *C. gapperi*. Evidently we were dealing with a single species of *Clethrionomys* at Churchill. Apparently many individuals moved from the woods out over the climax tundra during the period of high numbers.

C. gapperi has been recorded from a number of localities in northern Manitoba. Preble (1902) took one specimen on the Churchill River, 15 miles above Fort Churchill, and he reports another Churchill specimen in the U. S. National Museum. Hall and Cockrum (1953) follow Anderson (1947) in including Churchill within the range of *C. g. hudsonius* Anderson. Manitoba specimens of *hudsonius* in the National Museum of Canada are recorded from Ilford (Mile 286, Hudson Bay Railway), Bird (Mile 349), and Churchill (Mile 510) by Anderson (1940), and from Sandhill Lake by Anderson (1947).

Nineteen Churchill specimens taken in 1952 and 1954 were compared with topotypes of *hudsonius* from Kapuskasing, Cochrane District, Ontario, in the Royal Ontario Museum. The rustry red-brown dorsa of the Churchill specimens were not as vivid, and the sides were more drab than typical *hudsonius*. In most individuals of a large series of *hudsonius*, the underparts were markedly yellowish and this colour merged with the bright buffy colour of the sides, while in the majority of the Churchill specimens the belly hairs were distinctly white at the tips (although very slightly yellowish in a few individuals). In all cases, however, the whitish bellies contrasted sharply with the buffy-drab sides.

Several large series of northern Ontario specimens in the R.O.M.Z.P. are closely comparable to the Churchill individuals examined. The locality nearest to Churchill from which comparable specimens were taken is Fort Severn. Specimens from several inland localities in Kenora District, Ontario, are similar.

That our knowledge of the distribution and relationships of the races of *C. gapperi* inhabiting Manitoba is currently in a rather incomplete and unsatisfactory state is apparent when one considers that various authors have included parts of central and northern Manitoba within the ranges of three races of *C. gapperi* besides *hudsonius*. Breckenridge (1936) recorded *C. g. gapperi* (Vigors) from Cormorant Lake, but Hall and Cockrum (1953) ascribed this record to *C. g. loringi* (Bailey) to conform with Anderson's (1947) definition of the range of *loringi*. However, as *loringi* is apparently a race inhabiting prairie groves, and as Rand (1948) recorded *C. g. athabascae* (Preble) from near Flin Flon, which like nearby Cormorant Lake is in the boreal forest, the present authors would expect that the Cormorant Lake specimens should be ascribed either to *athabascae* or to an undescribed race. The status of these specimens as well as that of the Churchill ones is sorely in need of review. The complex problem of speciation in *Clethrionomys* in northern Manitoba is currently being investigated by personnel of the Royal Ontario Museum as part of a wider, trans-continental question requiring further study.

Phenacomys intermedius mackenzii Preble. Phenacomys vole.–In late July, 1952, Smith collected two immature males from area Z. From time to time during the summer of 1953, Barlow trapped for lemmings in dry tundra areas and occasionally caught "yellow-nosed field mice." It appears likely that these were phenacomys. Between June 30 and July 4, 1953, Gunderson trapped six individuals in the Labrador tea-larch-spruce forest along the north shore of Landing Lake. He retained four males and one female, all adults.

In 1954, Foster found an unprecedentedly high population of phenacomys, and concentrated most of his spare time on catching them alive and studying these rare microtines. By the end of the summer, 32 had been caught that remained alive in captivity; 18 young had been born to four of these; 36 had been skinned; and the skulls and measurements of 14 others had been saved, making a total of 100 phenacomys. Of these, the 50 live individuals were flown to the R.O.M.Z.P. where survivors are now under study.

In 1955, 192 captures (including 45 recaptures) of phenacomys voles were made in traps, and 15 additional phenacomys were caught on turning over boards, logs, stumps etc. From

these animals and their offspring born in captivity, 89 skins and skulls and 42 skulls only were saved, and 49 were flown alive to the R.O.M.Z.P.

The average standard measurements for 49 animals (27 ♂♂, 20 ♀♀, and 2 sex undetermined) taken in 1954 are: total length, 131 (111–152); tail, 32 (23–40); hind foot, 19 (17–20); weight, 27.4 (15.5–46.7).

The mean number of embryos, newborn offspring, or placental scars from 37 breeding females examined between June 15 and September 3 in both 1954 and 1955, was 4.9 with a range from three to eight. The total lengths of pregnant females varied from 111 to 152 mm. Males with enlarged testes were taken from June 5, which was the earliest date on which a phenacomys was caught, until August 18.

In 1954, phenacomys were found to be most numerous in open white spruce woods with trees five to twenty yards apart, on generally well-drained ground littered with logs and stumps, but with an overall, scanty ground cover. Common plants found here include *Cladonia* spp., *Salix* spp., *Empetrum nigrum*, *Shepherdia canadensis*, *Vaccinium uliginosum*, *Arctostaphylos rubra*, *Betula glandulosa* and *Epilobium angustifolium*. Phenacomys were also trapped on the climax tundra, where three were found hundreds of yards from the nearest trees by Barlow in 1954. The fact that fewer traps were set on the tundra than in woods might partially account for fewer phenacomys being caught on the tundra. About a dozen were taken in rather wet spruce woods, while nine were caught in the Labrador tea-larch-spruce forest north of Landing Lake.

The Churchill woods that yielded the most phenacomys in the summer of 1954 (area B) was most similar to the dry, open heath-jack pine association of western Quebec where Foster and others on an R.O.M.Z.P. field party led by Dr. R. L. Peterson, found phenacomys very abundant in 1953.

In 1955, Foster trapped in a great variety of habitats and found phenacomys in all but dense grass and sandy tundra. One pregnant female, caught under a small piece of tar paper near Ft. Prince of Wales (across the river from Churchill townsite) was about 2½ miles from the nearest trees. Many were caught on dry, hummocky, scrubby willow tundra, while many others were taken in extensive pure willow thickets, the willow being as tall as eight feet. Even the wettest of moss-willow habitats, with the water table two to four inches below the surface, were found to have phenacomys and a few meadow voles. Indeed, apparently the only common denominator of phenacomys habitat requirements is scrubby vegetation, with willow usually predominating.

In searching for phenacomys, Foster looked for holes in the ground or cavities under logs and stumps; holes which contained fresh shoots of *Salix* spp., *Shepherdia*, *Vaccinium* or *Arctostaphylos* signified recent activity of phenacomys or red-backed voles. As red-backs fed on *Epilobium* also, meadow voles ate *Petasites sagittatus*, and phenacomys apparently ate neither, the presence of these plants in caches was a negative indication of phenacomys. Frequently a trap placed at a hole caught a phenacomys and a red-backed vole on successive nights.

Of the 15 phenacomys caught by hand, all but two were beside or in their nests at time of capture. The nest was usually under a piece of cardboard or plank, but on five occasions, it was located under a log or stump. The nest of shredded paper, moss, or other plant fibre was never more than a few inches below ground level. Only once was it inside a log. Tunnels were generally short; those connecting holes were no more than a few feet long. Defecation usually took place in one spot not far from the nest. Fresh faeces of phenacomys have a characteristic aromatic odour.

The mummified carcasses of 18 phenacomys, five meadow voles and six varying lemmings were found scattered over the countryside, usually lying in the open, though occasionally in a nest, the individuals concerned having apparently died the preceding winter. These findings seem to indicate that phenacomys are more vulnerable to cold, disease, or other factors than other Churchill microtines.

Of all the Churchill small mammals, the phenacomys is the easiest to handle. It usually

makes little effort to escape, and only very rarely bites. Occasionally it was seen in the wild, confidently sitting beside its hole eating a willow shoot. Possibly its general lack of fear is an important reason for its remains being so numerous in owl pellets (87 out of 273 skulls), while it apparently is not the most plentiful microtine.

Previous reports of phenacomys are scarce. Preble (1902) collected four specimens at Churchill during mid-summer 1900. Anderson (1942, 1947) records a Churchill specimen in the National Museum of Canada. Rand (1948) records a single specimen taken by Bryenton near Flin Flon in 1945, and Manning (1948) took another at Malaher Lake, N.W.T. (ca. 150 miles northwest of Churchill) the same year.

In contrast to the scanty number of specimens taken in the past in northern Manitoba and indeed elsewhere in eastern Canada, there are several recent reports of comparatively large numbers of phenacomys. For instance, high populations of eastern phenacomys have been reported near Authier-nord, Quebec, in 1953 by an R.O.M.Z.P. field party; near Fort Chimo, Quebec, by Bateman (1953) also in 1953; near Sutton Lake, Ontario, in 1954 (R. L. Peterson) and at Churchill in 1954 and 1955 in the present account. This makes one wonder whether these voles are really so rare, or whether sufficiently intensive trapping had ever been carried out in the proper habitats. Present and future mammalogists shall surely remedy this situation.

Some workers such as Anderson (1942, 1947) have considered the yellow-nosed phenacomys voles from east of the Rockies as *P. ungava*, a species distinct from the brown-nosed *P. intermedius* of the west. The authors tentatively agree with this view, pending further investigation of the taxonomy of the genus, now that comparatively large numbers of specimens are available. Further details of this and other aspects of recent studies of the biology of phenacomys voles will be published subsequently.

Microtus pennsylvanicus aphorodemus Preble. Meadow vole.—The only vole observed by Smith in 1951 was an immature of this species taken by hand on June 13 in a wet sedgy area bordering lichen tundra. However, during the summer of 1952 meadow voles were very abundant; Smith trapped 60 individuals in area Z and observed 73 alive in the field. This latter figure includes a total of 25 young in three nests, and many voles taken by hand. Seven skins and skulls were retained. Copps and Barlow (personal communications) of D.R.N.L. report that voles were still abundant in 1953. Gunderson trapped two on the coastal rock ridge and four in the open, spruce-larch woods near Landing Lake; all six specimens were retained. Meadow voles were again very numerous in 1954. Foster trapped only 17 (mostly in grassy parts of areas C and D), but took many by hand under beach debris. He retained one specimen. In 1955, he trapped eight in a dense spruce woods (area C) and 18 on levees and moist mossy meadows. Fresh nests were numerous under litter along the grassy bay shore, though their occupants were somewhat less common than in 1954. One skin and skull and four skulls were retained for the R.O.M.Z.P.

Two skulls from Churchill collected by Mrs. A. F. MacIvor, and five skins and skulls taken in early August, 1950, by A. G. Edmund, are also in the R.O.M.Z.P.

Fairly complete records of the breeding condition of meadow voles taken in 1952 were supplemented by a few notes from Edmund's 1950 specimens, Gunderson's 1953 data, and Foster's 1955 specimens. Breeding data on 45 females and 38 males from Churchill are available.

The onset of the breeding season occurred before trapping commenced, probably in late April or early May. The earliest breeding record available was a nest containing a lactating female and six small, blind, furred young on June 1, 1952. Five days later, a second nest with seven active young was discovered. The total length of one young was 80 mm. Another nest found on June 12 contained 12 blind, furred young. The first pregnant females were seen on June 2 and 3, and one taken alive on June 12 produced five young six days later. Half-grown young were seen on June 19.

The latest pregnant females were taken on July 28, 1952, and August 5, 1950, although two lactating females with uterine scars were taken in late August and another on September 3, 1952. Three large males with enlarged testes were taken in late summer, 1952, but

their testes likely were regressing after the end of the breeding season, which appeared to terminate in early August.

Of the 45 females taken in 1950, 1952, 1953 and 1955 for which breeding data are available, 23 were not pregnant. Seventeen pregnant females carried from 4 to 12 embryos. This upper extreme appears to be higher than any previously reported. Two litters of 12 were recorded in 1952. Besides the nest containing 12 young already mentioned, 12 embryos were found on July 11 in a female measuring 194 mm. long—the largest meadow vole seen at Churchill. The mean number of embryos in 17 pregnant females was 6.9. In addition, five lactating females had from six to nine placental scars, averaging 7.8 per animal. The mean size of these 22 litters is 7.1 young, which is considerably greater than the mean number of young of 4.35 from 23 pregnant uteri of *M. p. pennsylvanicus* (Ord) from Temagami, Ontario, recorded by Coventry (1937). This point appears to be the boreal forest locality nearest to Churchill from which breeding data are available. The present data tend to refute Coventry's suggestion that there may be a reduction in litter size northward in this species as was indicated by his data from two Ontario localities.

Figure 2 shows the relationship between litter size (number of embryos or scars per female) and total length. There is a tendency for larger and presumably older females to have larger litters, as has been shown for *M. californicus* by Hatfield (1935) and for *M. ochrogaster* by Jameson (1947).

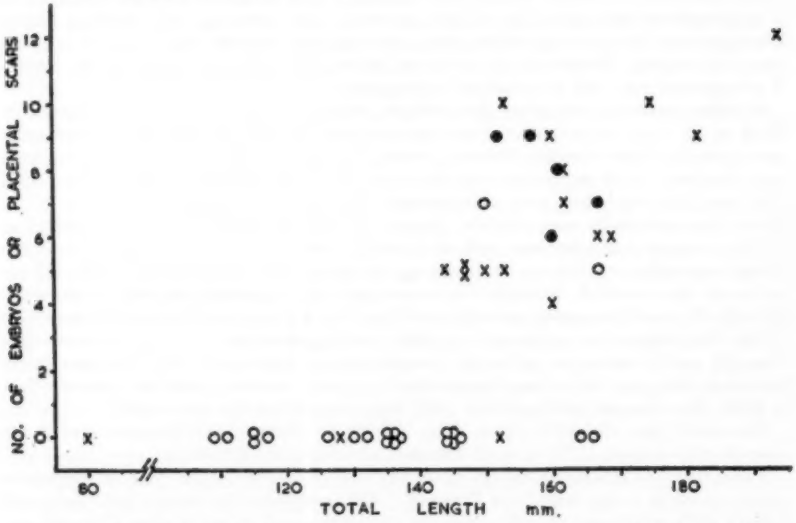

FIG. 2.—Litter size in 45 female *Microtus pennsylvanicus*. Crosses indicate specimens taken May 27 to July 13; open circles indicate those taken July 14 to September 2; and closed circles represent lactating females with placental scars, taken July 14 to September 2.

Examination of the data of Figure 2 reveals further reproductive characteristics of female meadow voles. Only three of 18 females taken earlier than July 14 were not pregnant, and of these, two were small individuals (total lengths 80 and 128 mm.), undoubtedly young of the year. The 15 pregnant females varied from 144 to 194 mm. in total length.

Only two of 27 females taken from July 14 to September 3 *were* pregnant; their lengths were 150 and 167 mm. respectively. During the same period, five lactating females with uterine scars were taken; these were in the same size range as the pregnant individuals,

from 152 to 167 mm. Only two *large* females taken after mid-July were not pregnant or lactating; they were taken August 20 and September 2, and measured 166 and 164 mm. The remaining 18 females taken after July 14 were all 146 mm. or less in total length, and all were not pregnant. These presumably were young of the year, and it appears that they did not breed in their first summer, unless breeding resumed in the fall after our trapping ceased. These data suggest also that female meadow voles mature sexually at about 146 mm. in total length.

A similar graphic method was used for analysing the breeding data for male meadow voles. In Figure 3 the lengths of testes have been plotted against total length for each of 38 males. Figure 3 shows that these animals may be divided into two groups on the basis of length of testes. The first group includes 16 males with large testes (10–17 mm.); eleven that are larger than 146 mm. in total length were taken before mid-July. These voles were likely born the previous summer. Probably in the same age-group are three others that are larger than 146 mm., which were taken in late August and early September. Figure 3 shows that their testes were smaller than those of individuals of approximately the same total lengths taken before mid-summer. Probably the testes of the three animals taken in late summer were regressing in size and activity after the end of the breeding season. These 14 large individuals were probably adults in both age and sexual maturity.

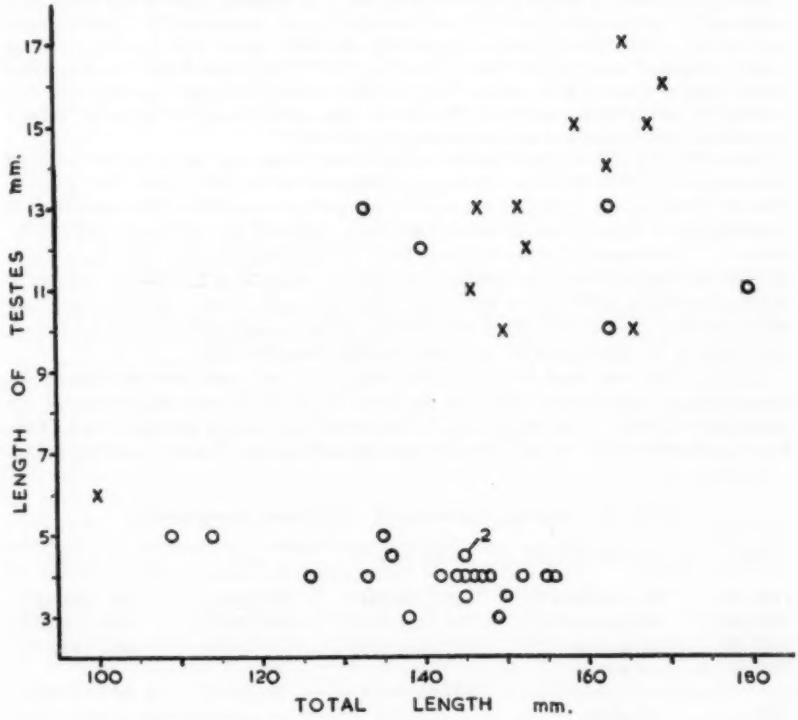

FIG. 3.—Length of testes of 38 male *Microtus pennsylvanicus*. Crosses indicate specimens taken May 27 to July 17, and open circles represent specimens taken July 21 to September 9. The numeral "2" indicates that two individuals had the same total length and testis length.

The remaining two males with large testes, taken in early August, were less than 146 mm. in length. They may have been young of the year that had matured sexually and joined the breeding population. These might be termed subadults.

The second group includes 22 males with small testes (3–6 mm.). Only one individual (an immature, 100 mm. long) was taken before mid-July. Of the 21 males with small testes taken between July 21 and September 9, eight were 146 mm. or greater and 13 were less than 146 mm. All 22 individuals with small testes were undoubtedly also young of the year, and they likely would not breed until the next spring.

Except for the two individuals that have been called subadults, it appears that the males examined reached sexual maturity at a total length of about 146 mm. This length at which maturity was attained coincides with that for females described earlier.

It appears that there is a short breeding season commencing about late April and continuing until mid-summer. The data for both males and females suggest that at Churchill *most* young of the year did not breed in their first summer, unless breeding resumed in the fall after trapping ceased. The present data thus suggest that the breeding behaviour of Churchill meadow voles vastly differs from that of meadow voles from more southern regions, which begin breeding at an early age according to Bailey (1924) and breed throughout the whole year when the population is high, as recorded by Hamilton (1941).

Such a difference in length of the breeding season in different parts of the range as is suggested for the present species is known for its European counterpart, *M. agrestis*. Baker and Ranson (1933) record that in England the breeding season lasts from February or March to September or October, whereas Bourlière (1955) states that it lasts the year round in the south of France. It is obvious, however, that considerably more breeding data concerning *M. pennsylvanicus* at Churchill must be collected and analysed before the foregoing tentative conclusions and speculations are proved valid.

For conformity with the other species accounts, the means and ranges for the standard measurements of 65 individuals (64 taken in 1952 and one in 1954) have been given in Table 2. However, the measurements of obviously young animals have been considered in calculating these means. Data presented earlier have suggested that both males and females mature at a total length of about 146 mm. Mean standard measurements have been calculated for all animals taken from 1950 to 1953 that are longer than 146 mm. or that are in breeding condition. Table 2 also gives these data for females, males, and both sexes, and shows that they are almost identical with Preble's (1902) averages for seven adults (which he ascribed to *M. drummondii* = *M. p. drummondii*) from Churchill.

Meadow voles were found in every habitat studied, but they were most abundant in the damp, grassy or sedgy tundra and on the dry grassy beach. They were also common in and around open woods (as in area Z) where lush sedges and grasses provided cover. Both grasses and sedges were cut and eaten by meadow voles, as was *Petasites sagittatus* which

TABLE 2. — *Average measurements* of Microtus pennsylvanicus*

YEAR	NUMBER AND SEX	TOTAL LENGTH	TAIL	HIND FOOT
1952, '54	32 ♂ ♂ - 33 ♀ ♀	147 (80-194)	37 (22-47)	19 (14-21)
1950-53	23 mature ♀ ♀	160 (144-194)	40 (31-47)	19.5 (19-20.5)
1950-53	21 mature ♂ ♂	154 (133-180)	39 (32-46)	19.5 (18-21)
1950-53	44 mature ♂ ♂ and ♀ ♀	157 (133-194)	40 (31-47)	19.5 (18-21)
1900	7 adults (Preble, 1902)	156	40	19

* mean (minimum-maximum) in mm.

grew commonly in damp clearings and edges of woods. *Petasites* was frequently found pulled into their burrow entrances.

Ectoparasites (fleas, Anopluran lice, and mites) were found on several voles, but no helminths were seen in the gastro-intestinal tracts of about 60 carcasses briefly examined in 1952.

Published records of meadow voles from northern Manitoba are from: Churchill, by Preble (1902), Breckenridge (1936), Rand (1944) and Anderson (1947); Cape Churchill, by Preble (1902); Nonala (80 miles north of Churchill) by Breckenridge (1936); Herchmer, by Rand (1944); and near Flin Flon by Rand (1948).

The true subspecific status of meadow voles from Churchill is not clear at present. Various authors have ascribed Churchill specimens to *M. p. aphorodemus* Preble or *M. p. drummondii* (Audubon & Bachman) or as intergrades.

Preble (1902) described *M. aphorodemus* (= *M. p. aphorodemus*) from the Barren Grounds about 125 miles north of Churchill. His 22 specimens from 10 miles north of Hubbart Point, and 10 specimens from Cape Churchill are referred to *aphorodemus*, while some Churchill specimens among the large series called *drummondii* "seem to incline to *aphorodemus*." Breckenridge (1936) ascribes his Nonala specimens to *aphorodemus* and those from Churchill to *drummondii*.

Rand (1944) refers to 27 specimens of *drummondii* from Churchill in the National Museum of Canada and concludes that this race intergrades with *aphorodemus* there. Nine specimens "show an approach to this form" and he considers them to be *aphorodemus*. Anderson (1947) states that specimens of both races from Churchill are in the National Museum of Canada. However, Hall and Cockrum (1953) cite only Anderson's reference to *aphorodemus* at Churchill, and regard all Churchill meadow voles as members of this race.

The usage of the latter workers has been followed here for conformity. However, a detailed comparative study of a large series of Churchill specimens with those from neighbouring areas is called for to confirm this seemingly arbitrary exclusion of Churchill from the range of *drummondii* by the latter authors. Similarly, the status of the specimens regarded as intergrades by Preble (1902), Rand (1944) and Anderson (1947) should be examined carefully to attempt to resolve the present unsettled situation.

Microtus xanthognathus (Leach). Chestnut-cheeked vole.—There are no recent reports of this species at Churchill. Preble (1902), who did not collect it himself in 1900, cites old records from Fort Churchill and Nelson River. Recent authors, including Anderson (1947) and Hall and Cockrum (1953), merely cite Preble's reference to these old records.

Ondatra zibethicus albus (Sabine). Muskrat.—Muskrats were rare in the Churchill area from 1951 to 1955. The authors made no special efforts to observe them, and no specimens were collected. In 1952, one skull was found in area Z. Near here, wide runways entered a small pond from a large, unoccupied house of sedges on the bank. In 1954, Foster saw one muskrat enter a hole in a dyke between the town and camp. In 1955, one skull was found in area C. In September, 1955, three young individuals appeared among the buildings at the military camp.

When one considers that the shallow tundra ponds and lakes are frozen to the bottom for nearly half of each year, it is not surprising that muskrats are not common at Churchill. The few individuals that do occur probably inhabit the Churchill River system, and some of these apparently move over the tundra to the smaller ponds during the summer.

Preble (1902) found Muskrats at Churchill in but one place—a stream entering the Churchill River a few miles above the post. Hall and Cockrum (1953) cite Hollister's (1911) record from Fort Churchill. Shelford and Twomey (1941) record one nest at the edge of a small pond but state that "no recent signs of the animal were evident." Rand (1948) records muskrats from west-central Manitoba.

Preble (1902) described a new muskrat *Fiber zibethicus hudsonius* from Fort Churchill. This is at present considered a synonym of *O. z. albus* (Sabine) by Hall and Cockrum (1953).

Lemmus trimucronatus trimucronatus (Richardson). Brown lemming.—A single specimen was taken at Churchill in 1953 by Quay (1955). This species has apparently not previously been reported from the west shore of Hudson Bay south of the mouth of the Thlewiaza River (about 50 miles north of 60° latitude) where it was taken by Preble (1902).

Synaptomys borealis smithi Anderson and Rand. Northern bog lemming.—In 1952, Smith examined five Churchill specimens and another was reported to him. The skins and skulls of three animals taken in area Z were retained. In 1954, Foster live-trapped six individuals, but none lived in captivity for more than two days. All six were retained as specimens. They were collected in the wet, low-lying, open, spruce woods; in the dry, open *Cladonia*-spruce association; and in the dense, Labrador tea-larch-spruce forest below the treeline. The only 1955 specimen was taken alive by Dr. E. Kuitunen of the Ontario Department of Health, on dry, rocky, hummocky tundra. Like those taken in 1954, it died on the second day of captivity although it had eaten much fresh grass, and was almost continually active.

The average standard measurements for 10 animals (6 males, 2 females, and 2 sex undetermined) taken in 1952 and 1954 are as follows: total length, 118 (110–150); tail, 23 (18-28); hind foot, 19 (18-20); weight, 21.3 (15.2–27.2).

Neither of two females examined showed any evidence of breeding. The testes of five males had the following lengths: 1.5, 2, 3, 5, 6 mm. About 30 mites collected from one 1952 specimen were turned over to the Northern Insect Survey party.

This species has been taken at several localities in northern Manitoba, but has only once been reported from Churchill, by Quay (1955) who collected four specimens in 1953. Preble (1902) trapped two specimens about 300 miles to the south. Breckenridge (1936) took one at Cormorant Lake, Mile 42, Hudson Bay Railway. Anderson and Rand (1943) described *S. b. smithi* from Thicket Portage, Mile 165, Hudson Bay Railway, and they mention four Ilford specimens (Mile 286, H.B. Railway). Rand (1948) notes that one specimen was taken by Bryenton near Flin Flon in 1945.

Dicrostonyx groenlandicus richardsoni Merriam. Varying lemming.—In the years under consideration here, the numbers of lemmings at Churchill have fluctuated greatly. Residents of Churchill reported that lemmings were abundant in the summer of 1949, and much less common in 1950. The lowest numbers in recent years occurred in the summer of 1951 when only six specimens were collected by Smith in spite of extensive searching and some trapping. Lemmings were slightly more common in 1952 although they were not nearly as numerous as in the following two summers. In 1952, a few lemmings were captured alive, seven dead specimens were examined and the skins and skulls of three retained by Smith.

Copps and Barlow (personal communications) report that there were many more lemmings around Churchill in 1953, and that more than 100 were trapped during the summer by various workers at DRNL. In 1954, Foster managed to catch ten lemmings although his trapping was mostly confined to woods or their borders. Eight individuals were kept in captivity and two were retained as specimens. While live lemmings could be captured without difficulty under rocks or in burrows on the tundra in May and June, the task of finding them became increasingly difficult during the latter half of the summer, and they were rather scarce in the fall. In spite of this, lemmings appeared somewhat more numerous in the spring of 1955 than in the preceding fall. Again their numbers appeared to decrease to an ever lower level as the summer progressed. Hand captures were almost nil and only five were trapped in spite of many tundra trap-nights.

The average measurements of 10 lemmings (2 males, 7 females, and 1 sex undetermined) taken in 1951, 1952 and 1954 are: total length, 130 (108–148); tail, 11 (6–15); hind foot, 18 (14–20); weight, 65.1 (56.2–72.6).

Nearly every female lemming examined was pregnant or lactating. As information about breeding in wild *Dicrostonyx* is scarce, our data for 10 females are set forth in Table 3. The first young of the year observed by Smith in 1952 was taken on June 16; by comparison

TABLE 3. — *Breeding data from 10 female varying lemmings*

DATE	NUMBER OF EMBRYOS OR YOUNG
June 30, 1951	Pregnant ♀ taken June 25 gave birth to 5 young
July 19, 1951	5 large embryos (C R M 17 mm.)
May 27, 1952	4 embryos
June 4, 1952	4 small embryos; lactating ♀
June 6, 1952	3 large embryos (C R M 20 mm.); lactating ♀
June 19, 1952	5 small embryos
July 14, 1952	Pregnant ♀ gave birth to 4 young
July 31, 1952	4 large embryos
August 7, 1952	traces of placental scars
July 13, 1954	♀ with 9 two-week old young in nest

with laboratory-raised individuals it was judged to be about 21 days old. On May 26, 1954, Foster found two approximately three-week old young in a nest under a box. The mean size of the nine litters listed in Table 3 is 4.78 (range 3 to 9). In spite of the few litters involved, this mean is comparable to the mean litter size of 4.53 reported by Manning (1954) for wild *D. groenlandicus*. Preble (1902) records that "every litter found consisted of three and in each pregnant female were three embryos." This surprising lack of variation is perhaps explained by his statement that "pregnant females were not common."

Manning (1954) reports that when pairs of captive lemmings were left together, re-fertilization was normally effected at post-partum oestrus. He records an observation of a pregnant, lactating female lemming on Banks I., and cites Preble's (1902) record of a pregnant female suckling three young. Smith's two records of pregnant, lactating females at Churchill in 1952, during the build-up in the lemming population, provide further evidence that Manning's laboratory observations (confirmed by our own data on captive lemmings) represent the actual behaviour of the lemming in the field rather than a response to captivity. The natural occurrence of copulation immediately after parturition has been reported in several other microtines, including *Clethrionomys gapperi*, *Ondatra zibethicus*, and *Microtus pennsylvanicus*, by Hamilton (1949).

All lemmings collected by the authors were taken in dry habitats; most were in the beach area, or in the climax tundra, especially along rock ridges and eskers. However, one *Dicrostonyx* was seen in 1952 in area C, which is a forested area surrounded by climax tundra. That individual entered a burrow under the sloping base of a white spruce. In 1954, Foster captured four lemmings inside the border of the same woods.

Common tundra plants known to be eaten by lemmings are *Dryas integrifolia*, *Arctostaphylos* spp., and *Salix Richardsonii*.

Fort Churchill is the type locality for *D. richardsoni*, which was described by Merriam (1900). Preble (1902) collected about 80 topotypes, and he records detailed observations on some of the ecological and morphological characteristics of this lemming. Breckenridge (1936) collected four adults and five juveniles at Churchill in 1933. Shelford and Twomey (1941) found that these lemmings formed the largest volume of the food of nesting snowy owls and rough-legged hawks at Cape Churchill in 1936. Anderson and Rand (1945) record specimens from Churchill in the National Museum of Canada.

According to Rausch (1953) who has followed several old-world workers in treating *D. groenlandicus* as conspecific with the palaearctic species, the name for the race inhabiting the Churchill region would be *D. torquatus richardsoni* (Merriam).

Mus musculus domesticus Rutty. House mouse.–T. P. Copps gave Smith an adult male taken outside his house in the townsite on August 31, 1952. The skull was retained in Smith's collection. Apparently this species has not hitherto been recorded from Churchill,

although some individuals have undoubtedly been introduced previously from ships. Preble (1902) cites two old records from buildings at York Factory.

Zapus hudsonius hudsonius (Zimmermann). Meadow jumping mouse.—During 1952 Smith trapped one adult and four immatures in area Z, and one specimen was retained. The R.O.M.Z.P. has single specimens from The Pas and Ilford, and three skins and skulls collected near Churchill in July, 1950, by A. G. Edmund.

A female taken on July 7, 1950, contained six embryos. Another taken on August 5, 1952, was lactating, and her uterus bore six placental scars. Four immatures were taken on August 20, August 21 (two), and Sept. 2, 1952.

The four Churchill specimens examined are almost identical to topotypes of *Z. h. hudsonius* from Fort Severn, Kenora District, Ontario, in the R.O.M.Z.P.

Preble (1899) records from Fort Churchill a "part of a skin . . . " which had "evidently been in alcohol." The same author (1902) obtained an imperfect skin from natives of Churchill. Rand (1948) records specimens taken near Flin Flon in 1945. Specimens from several localities in north-central Manitoba examined by Krutzsch (1954) were all referable to this form.

SUMMARY

The authors studied small mammals at Churchill, Manitoba, during the summers of 1951, 1952, 1954 and 1955. The notes are augmented by a few records of specimens in the Royal Ontario Museum of Zoology and Palaeontology and by unpublished data of other workers.

An annotated list includes 15 species. Of these *Sorex palustris*, *Mustela rixosa* and *Mus musculus* have not been previously reported from Churchill. Published records are summarized and observations and comments on abundance, breeding, habitat, food and taxonomic status are presented for most of the species listed, and for several microtines in particular. Especially noteworthy is the report of an abundance of the phenacomys vole with a description of various details of its biology, hitherto poorly known.

Changes in the numbers of microtines from summer to summer are noted. Voles increased markedly one year before lemmings became common; voles remained abundant for four consecutive summers, and long after the decline in lemming numbers. Comments are made on the food habits of several avian predators the abundance of which appears to be correlated with the numbers of microtines.

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GESTATION PERIOD, BREEDING AND FAWNING BEHAVIOR OF COLUMBIAN BLACK-TAILED DEER

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The determination of gestation period and observation of breeding and fawning behavior of animals in the wild are generally difficult; data concerning these fundamental aspects of deer biology are, therefore, often fragmentary and of a subjective nature. Much of our information concerning gestation period and behavior of deer has been obtained through observations made in zoological parks or other unnatural situations. Although these observations are of considerable value, bias may be introduced when these types of data are applied to wild animals. While engaged in the study of reproductive performance of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) the writer was able, through the facilities of the Deer Project of the State of Washington Department of Game, to minimize both of the above difficulties by observation of a herd of semi-wild deer which could be penned during the observation period.

Methods.—The herd utilized for this experiment consisted of 11 does and 1 three-year-old buck. Four of the does were mature (over 1.5 years old) and 7 were yearlings. The pens in which the experiment was conducted consisted of eight individual fenced enclosures, 84 by 15 feet, connected by a five-foot-wide alleyway running along one side of the pens. A scale house for weighing the deer, with a large window overlooking the pens, was situated in the center of the alleyway.

Before the breeding experiments the herd lived in a semi-wild state. The animals were unpenned and were allowed to run and browse at will. Approximately three quarts of wheat, barley or oats were made available daily to the entire herd in a feed trough near the pens. Before the hunting season (October) these animals were driven into the pens and were fed alfalfa hay and wheat.

The breeding experiment was begun on November 2 and completed on December 14. It was anticipated that this spread of time would allow for possible extremes in breeding periods, since the estrous cycle of deer is about 28 days (Cheatum and Morton, 1942). Observations were made for two out of every four hours at the beginning of the experiment, but it was soon found that an hour of observation in the morning and evening was sufficient. Attempts were made to observe the deer at night but this was found impractical.

The buck was placed with the does for an hour twice daily, at daylight and at 4:00 P.M., and observations were made from the scale house. When observations were completed the buck was driven back to a separate pen, while the does were allowed to run at will through five pens. The remaining pens were used to hold additional deer. After completion of the breeding experiment the does were released but were kept in the vicinity of the pens by feeding

the daily supplement of grain. These does were weighed weekly during the winter period.

On April 22, the pregnant deer were placed in a 20-acre holding pen, containing natural browse, to facilitate their capture before parturition. Approximately two weeks before fawning, each doe was moved from the holding pen to the fawning pens. Four of these pens were enclosed in camouflage cloth to prevent disturbances to the deer. While in the fawning pens, the does were fed alfalfa hay, grain and assorted browse, usually consisting of bitter cherry (*Prunus* sp.), vine maple (*Acer circinatum*), willow (*Salix* sp.), blue huckleberry (*Vaccinium parvifolium*), and red alder (*Alnus rubra*). Grass and some forbs were also available in the pens. Each doe was allowed access to three pens and was weighed daily. The fawning pens were examined for evidence of parturition several times during the day, from 6:30 A.M. to 9:00 P.M.

Results and Discussion.—Breeding experiments have been carried out by several investigators to determine breeding history. In New York, Cheatum and Morton (1942) had females bred to determine gestation period of the whitetail deer (*Odocoileus virginianus borealis*). In Arizona, Nichol (1938) carried on breeding experiments incidental to feeding experiments. Haugen and Davenport (1950) also ran breeding experiments in conjunction with feeding experiments in Michigan. Gerstell (1936), in Pennsylvania, used breeding experiments to determine productivity of deer. Dixon (1934), in California, made field observations of the gestation period and behavior of black-tailed deer. The gestation period for *Odocoileus*, as determined by the above workers and by other observers, ranged from 189 to 222 days and averaged 200 days.

During the breeding experiment four mature does and one yearling doe were bred. These does bred from November 7 to 25 (Table 1). Three does, one two-year-old and two three-year-olds, gave birth to twin fawns. Three additional yearling does, bred in the wild after the breeding experiment terminated, bore single fawns. Birth of fawns occured from June 2 to July 10. The gestation period of the five does averaged 203 days and ranged from 199 to 207 days (Table 1). This figure for black-tailed deer was similar to that for deer generally determined by other workers.

Six does gave birth to fawns in the morning, one at noon, and the remaining does in the early evening. The does with twin fawns lost an average of 18 pounds at fawning and those with singular fawns lost an average of 13 pounds.

TABLE 1. — *Gestation periods of five penned black-tailed deer*

DEER NUMBER	CONCEPTION	PARTURITION	GESTATION
1995	Nov. 7	June 2	207 days
1895	Nov. 12	June 3	203 days
3750	Nov. 18	June 5	199 days
3288	Nov. 23	June 14	203 days
1898	Nov. 25	June 16	203 days

Seven males and four females were born. Weights of the fawns at birth ranged from 5.5 to 10 pounds and averaged 7.1 pounds (Table 2). Birth-weight records from four captured wild fawns showed that the average weight was 6.68 pounds; included in this sample was one set of twins.

TABLE 2. — *Productivity of penned black-tailed deer*

DEER NUMBER	AGE OF DOE AT FAWNING	NUMBER OF FAWNS	SEX OF FAWNS	WEIGHT AT BIRTH (LBS.)
1995	4 yrs.	2	♂, ♂	6.5, 6.5
1895	4 yrs.	2	♂, ♀	6.0, 6.0
3750	3 yrs.	2	♂, ♂	4.7, 5.5
3288	2 yrs.	1	♂	8.7
1898	4 yrs.	1	♂	10.0
3416	2 yrs.	1	♀	7.0
3428	2 yrs.	1	♀	7.5
3289	2 yrs.	1	♀	9.5

Breeding Behavior—Breeding behavior was classified into four stages: courtship, precoital, coital, and postcoital behavior. Courtship behavior was restricted to the male. When the buck was released from his pen, he immediately began an investigation of the pens and does. It was noticed that the buck would enter each pen and smell the ground and posts until he picked up the scent of a female in or approaching heat. He would then run, with his nose to the ground, following the scent to a particular pen or doe. If the buck happened on a spot where a doe had recently urinated he would smell the area and then lift his head, stretch his neck and retract his nostrils. This posture is described by Darling (1937) in red deer (*Cervus elaphus*) and is also common in domestic ungulates.

The buck seemed to be able to detect does approaching heat several days before the event. In the case of two does approaching heat at the same time, the buck ran from doe to doe at random. During courtship, the buck constantly tried to smell the doe's external genitalia and attempted to mount. The does evaded the buck when he approached too closely.

Precoital behavior began when the doe came into heat. When the buck was released he found the doe in heat and began to chase her. The doe first attempted to escape, but soon stopped and allowed the buck to serve her. This first attempt was never successful. The buck then rubbed muzzles with the doe, licked her head, tail and external genitalia. The doe was also noticed to rub her side against that of the buck and to lick his head and antlers. Intromission was not successful until the buck had mounted the doe five to seven times.

In actual coitus, when the penis was inserted into the vagina, the buck gave one powerful thrust, ejaculated and pushed the doe from him. The entire performance, from the time the buck made the first unsuccessful attempt at coitus until after ejaculation, lasted an average of six minutes.

In postcoitus, neither the buck nor the doe displayed further interest in the other. An interesting behavior was noticed in those does that had never been pregnant. Immediately following coitus, they squatted on the ground as if trying to urinate. Upon inspection it was noticed that their tails were fluffed and a yellow exudate was present around the vulva. These does continued this posture for as long as 20 minutes.

After coitus the buck was separated from the does. Although he was not allowed to breed a doe for a second time, it was possible that he might have done so. When he was released 10 hours later, he did not display further interest in the doe he had bred that day.

Fawning Behavior.—Approximately a month before fawning, the does were noticed to become quiet and less nervous during the weighing period, moving about less in the pens. It was also observed that the udders of the pregnant does began to swell approximately a month before fawning. Nichol (1938) described intense nervousness in mule deer (*Odocoileus hemionus hemionus*) immediately before parturition. Slight nervousness and pacing were observed in only two does prior to fawning. This lack of nervousness may have resulted from the security provided by the camouflage netting and the fact that the does were accustomed to being observed.

Fawning was observed in one instance. During the morning weighing period, doe No. 1895 was seen to be acting strangely. Closer observation revealed that she had given birth to one fawn and was licking the afterbirth from its back and legs. At 7:34 A.M. she rose to her feet and walked about the new-born fawn. The legs of a second fawn could be seen protruding from her vagina at this time. She then lay down and at 7:40 gave birth to the second fawn. By 7:47 she had licked the second fawn clean and eaten the afterbirth. At 8:20 A.M. the fawns were seen taking a few steps.

The first day after fawning the does spent considerable time licking and cleaning the fawns. This cleansing activity continued throughout the early life of the fawns. Although fawns were not observed to begin nursing immediately after birth, newborn fawns did make feeble attempts to find the does' udder. Very young fawns, a week old or less, spent most of the day sleeping; they rose only to nurse or move to a new hiding place. At this time they were easy to capture and handle; however, as the fawns grew older capture became considerably more difficult.

The does were definitely antagonistic toward fawns other than their own. When a fawn approached, the doe smelled or licked the fawn to determine its identity. If it was a strange fawn, she would kick or strike it with her forefeet and drive it away. Little friction was observed between individual does or fawns.

Summary.—The gestation period and breeding and fawning behavior of black-tailed deer were determined by observation of semi-wild deer penned only during the breeding and fawning periods. The gestation period as determined by this experiment ranged from 199 to 207 days with an average of 203 days. Breeding behavior was separated into four stages: courtship,

precoital, coital, and postcoital. The buck appeared to be able to identify those does coming into heat several days before external signs of heat were evident. The buck generally made from five to seven attempts to serve a doe before actual intromission was achieved. Parturition occurred most often in the early morning. Birth of the fawn was observed once; it took place in 13 minutes.

The writer wishes to acknowledge the assistance of Dr. H. K. Buechner, Assistant Professor of Wildlife Management, Department of Zoology, The State College of Washington, and of Gardiner F. Jones, Fred S. Zwickel and Homer I. Brent, Biologists, State of Washington Department of Game, in making this investigation and in preparing the manuscript. This paper was abstracted from a portion of a thesis for the Master of Science Degree at the State College of Washington, 1954.

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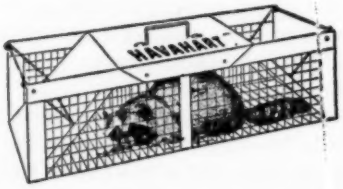

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GENERAL NOTES

TOOTH REDUCTION IN THE TUNDRA SHREW

It is well known that shrews are subject to striking skull variations, possibly more so than most mammals. Hooper (Jour. Mamm., 27:394, 1946) reported supernumerary teeth in *Sorex saussurei* as did Hibbard (Jour. Paleo., 27:21–32, 1953) in *Blarina brevicauda*. Jackson (N. A. F. No. 51:20, 1928) reported instances of reduction of tooth number in *Sorex obscurus* from Alaska. I would like to record an example of reduction in tooth number in a specimen of *Sorex tundrensis* from Alaska. This animal, a male, was taken between 20 November and 12 December 1955 in a cabin on the North Fork of the Huslia River at latitude 66°N., longitude 156°50'W., by Mr. R. A. Rausch of the Cooperative Wildlife Research Unit at the University of Alaska. I am indebted to Mr. Rausch for permission to report this specimen, which is now No. 816 in my collection and is destined for deposition in the collections of the University of Alaska.

The animal appeared normal in other respects, external measurements being 99×33×13, weight 6.4 grams. Standard skull measurements are: condylobasal length, 17.9 mm.; palatal length, 7.4 mm.; cranial breadth, 8.9 mm.; interorbital breadth, 3.8 mm.; maxillary breadth, 4.9 mm.; and maxillary tooth row, 6.4 mm. There appears to be only a negligible increase in size of the remaining unicuspids, but there is a space of nearly .2 mm. between the last unicuspid and the first cheektooth (P 4/). The anterior-posterior length of the unicuspid row is shortened in this specimen to 2.38 mm. from the average of 2.61 mm. for other *S. tundrensis* from this region. Judging by shape and cusp conformation, it appears to be the fourth unicuspid (P 3/) which is missing. The lower jaw appears normal in all respects.—WILLIAM O. PRUITT, JR. *Arctic Aeromedical Laboratory, Ladd AFB, Fairbanks, Alaska. (Current address: Box 282, College, Alaska.)* *Received February 25, 1956.*

SET HUNTING PATTERN OF A LITTLE BROWN BAT

Near Accord, Ulster County, New York, on the evening of October 1, 1955, while studying the bats about my yard my attention was suddenly attracted to a little brown bat (*Myotis lucifugus*) that was darting in and out from under the open porch of the house. Further watching indicated it was following a definite hunting pattern and with so much formality that I decided to give it special attention. Before it left that evening I was able to determine its actions.

A small porch, open on two sides, covers the two main entrances to the house, one entrance being that to the kitchen which is at a right angle to the main part of the building. A large sugar maple tree shades this portion of the house. The bat would come around the end of the house, to the front and in under the porch, banking or turning near the kitchen door, then retracing its path to the far side of the end of the house, turning and thence repeating the whole performance.

This hunting pattern was unique inasmuch as the bat would seldom deviate from its chosen path to pursue insects elsewhere about the lawn or adjacent areas. As it darted along it would frequently check its flight to snap up small insects (apparently dipterans) and on a few occasions small moths were taken. Some catches were made near the ground, while others were made off the side of the house. For the duration of its stay, the bat would methodically course back and forth over the same narrow path and would suddenly disappear as quickly as it had come. It would not be seen again until the following evening. The bat exhibited no fear of me as I stationed myself along its flight path or stood beside the kitchen door where it made most of its turns, often within a few inches of my face.

For thirteen consecutive evenings I witnessed this same feeding habit. As the month advanced the arrival time was progressively earlier. On October 2 the arrival time was 5:55 EST. On October 21 it was 5:23 EST. The length of stay was somewhat correlated with the existing temperature. Temperatures near 60° found the bat remaining for a period of about 20 minutes; at temperatures near 50° the period would last about 10 minutes. The bat did not appear on the 14th, 15th and 16th of October which was undoubtedly due to the storm period of that time. It returned on the 17th for one minute—the temperature 43°. It did not appear on the 18th although the temperature was 48°, but did return for its usual performance on the 19th, 20th and 21st. The temperatures were 47, 48 and 50° respectively. Colder weather settled in over the region on the 22nd and the bat was not seen again.—Fred Hough, *Research and Records, John Burroughs Natural History Society, Accord, New York.* *Received February 16, 1956.*

NOTES ON MATERNAL CARE IN *MYOTIS LUCIFUGUS*

On June 18, 1954, thirty female little brown bats, *Myotis lucifugus*, were taken from a maternity colony located in the White Memorial Sanctuary, Bentam, Litchfield Co., Conn. These females were kept in a large outdoor cage and observations were made on parturition and maternal care.

One newborn bat had been taken with its mother when the group was collected; the rest of the females dropped their young within a three-day period beginning June 20. No twinning was observed in this sample group, each female giving birth to only one young. The young emerged head first and were received into the interfemoral membrane. The females at this time secured themselves by their thumb hooks rather than assuming the usual inverted position. After a short adjustment period, the young migrated to the breast where they were thoroughly washed and then sheltered in the folds of the wing membrane. The long umbilical cord and placenta were not severed and eaten by the female but were allowed to dry and break off. The young, strangely enough, only were observed with the mother for about an hour and then they were seen wandering about the cage. The young soon banded together and were quite active, crawling about and exploring everywhere and tussling among themselves in much the same way as many other young mammals. Although undeveloped for flight, they were far from helpless.

When I first observed this apparent abandonment of the young, I assumed that it was due to the disturbances of captivity, particularly since there was much noise and confusion in the area. Consequently, I took several pre-term females and put them where conditions would be more like those of the colony, and yet the same behavior was observed. Both groups of young grew rapidly, but after the initial period with the mother, I was never able to observe the young suckling again. That they were feeding, I knew, for they lived and grew for eighteen days. Then all of the adults died due to an inadequate feeding formula and those young still alive declined rapidly in vigor and died within a day or two.

In June of 1955 I returned to the colony to see if this aggregation of the young was a part of the life history of this bat and not abandonment induced by captive conditions. Although the 105 to 108° of the attic in which the colony was located, and the ammonia fumes from the droppings, kept observation periods shorter than was desired, I was able to corroborate the findings with those of the captive animals. I reobserved the birth process and I also found several stillborn young with the placenta still attached and ear tabs still pressed to the head, among the droppings. Evidently stillbirth is not uncommon, for I had three in my captive group although I had assumed that they were induced by the disturbances inherent in captivity.

Most of the females were post-parturient and yet I saw only one or two young and these were newborn. It appeared that the conclusion drawn from the captive group might be correct, but I did not find my proof until the fourth day of observation when I received

permission to remove several boards and found an aggregation of eighteen young. Others undoubtedly could have been found had I been able to tear apart the attic. Those found were fully active as the captive group and crawled away as fast as they were able.

Whether the females are capable of recognizing their own young, or the young recognize their mothers, I am not prepared to say. However, in cages where one female and one young were kept, it was found that the young could be switched from female to female and that they would remain in good health and continue to grow. It would appear that these aggregations of young are formed soon after birth and that while they may be able to recognize their own mother, it is entirely possible that they suckle the most available female.

I would like to express my appreciation to Dr. Ralph M. Wetzel, Dept. of Zoology, Univ. of Conn. for his encouragement of this project and to the staff of Camp Townsend for granting access to the colony.—CHARLES E. ROTH, *Department of Zoology, University of Connecticut, Storrs.* *Received February 22, 1956.*

OCCURRENCE OF COATI IN NORTHERN ARIZONA

On January 30, 1956, one *Nasua narica pallida*, coati, "chulu," adult male was brought in to the Research Center of the Museum of Northern Arizona in Flagstaff by Mike Cullen, who had killed the coati while hunting lions at Babbitt Brothers Spur Cattle Company, T 11 N, R 12 E, Section 12, edge of Anderson Mesa, Coconino county, elevation 6000 feet. Its measurements were: length, 1210 mm.; tail, 575 mm.; hind foot, 112 mm.; ear at notch, 43 mm.; height at shoulder, 280 mm. Does this represent a migration to the plateau area of northern Ariona, or is this coati a soledados?—MILTON A. WETHERILL, *Museum of Northern Arizona, Flagstaff.* *Received February 27, 1956.*

ACCIDENTAL FATALITIES OF THE UTAH COUGAR

Fatal accidents to our larger carnivores under natural conditions are seldom recorded; this is particularly true of the cougar (*Felis concolor*). Because the cougar generally frequents remote, inaccessible places, has an extensive home range, and is relatively scarce, chances of finding accidental fatalities are poor. Evidence of even a heavy mortality would be widely scattered and we feel very fortunate in having discovered remains of two cougars whose deaths can be attributed to accidents. (In Utah, *Felis concolor* is commonly called cougar, mountain lion, or lion. Puma, the name favored by Young and Goldman [THE PUMA, MYSTERIOUS AMERICAN CAT: 2–4, 1946], is very seldom, if ever, used.)

Adult cougars in primitive surroundings, such as still exist in parts of Utah, apparently have little to fear from other wildlife species. Most accidents seem to result from the animals' method of getting food. Cougars hunt by creeping up as close as possible to their prey and then charging and springing on it. They must attain considerable speed on their charge and their momentum plus the struggles of their victim sometimes results in harm to themselves.

Some cases of non-fatal accidents to cougars have been recorded in the literature. Hornaday (THE MINDS AND MANNERS OF WILD ANIMALS: 278–279, 1922) reports the evidence of injury to a cougar in trying to capture a buck mule deer. The struggling animals toppled over a cut-bank and landed with the cougar underneath. The cougar was injured so badly in the fall it could not continue the attack and the buck escaped. Nelson and Goldman (Jour. Mamm., 14:221–222, 1933), writing of jaguars, state, "The great power and ferocity of their attacks are indicated by the fact that in 6 out of 92 skulls examined one or more of the canine teeth had been broken." By way of comparison, they remark, "In the puma (skulls), on the other hand, the canines are rarely broken, but nasal and frontal contusions exhibited by a considerable number are evidently the result of mishaps (to the animals) in bringing down their prey." A picture of a cougar skull with badly mutilated bones of the

facial region is presented by Connolly (Food Habits and Life History of the Mountain Lion [*Felis concolor hippolestes*], University of Utah Thesis, Fig. 29, 1949). Probably the animal had collided with some hard object while in pursuit of prey. Thus, from the cases cited, it can be inferred that by charging and pouncing on its prey in typical feline manner, the cougar occasionally receives injuries about the head.

A few accounts of fatal accidents have come to the attention of the writers. One published account is in the Administrative Bulletin of the U. S. Forest Service Intermountain Region (11:1, 1949). This publication relates how John O'Connor and Ray Westcott of Forney, Idaho, found where a cougar had attacked a bull elk. From the evidence of the tracks and other sign they concluded that the elk with the cougar astride its back had jumped down a mountainside and crashed against a tree, stunning both animals. Apparently, the elk had revived first and with its sharp forefeet had killed the cougar. Several of the cougar's ribs had been broken and a section of skin about a foot long had been torn from its back. Several newspapers printed slightly different versions of this encounter.

Loren Green of Salt Lake City, Utah, told Robinette about another cougar-elk episode in which the cougar was destroyed. In September of 1933 Mr. Green was a Civilian Conservation Corps enrollee camped in the Indian Creek area of the Salmon River region in Idaho. One day while hiking, he and a few friends found a recently killed elk calf. The only external wound noted was a long gash extending along its neck and shoulder. About 15 feet away was the fresh carcass of a medium-sized cougar which had been mutilated, apparently by numerous hoof thrusts of the calf's mother, for the immediate vicinity had been trodden down by hooves of a mature elk. It seems likely that the cow surprised the cougar and killed it with her forefeet.

Seton (LIVES OF GAME ANIMALS, 3:391, 1927) recorded a cougar fatality which was described in a letter written to him by Stanley G. Jewett, March 31, 1926, as follows: "One of the most interesting cases of Cougar killing Blacktail Deer came to my notice a few years ago when A. G. Ames, then predatory animal hunter in the employ of the U. S. Biological Survey, found the skeletons of a large buck Blacktail and an adult Cougar side by side at the base of a hemlock tree near the headwaters of the Clackamas River in Oregon. Ames and Ben Patton, a forest ranger, told identically the same story, that the Cougar skeleton was lying in a heap at the base of a tree, the bark of which showed a considerable amount of old scratches, while the Deer skeleton lay 8 or 10 feet away. There was a perfectly round hole on the top of the Cougar's skull which hole fitted one of the prongs of the Deer's antlers perfectly. This would indicate that at least once the Deer was a match for the Cougar, even though the encounter resulted in the death of both."

The two cases we interpreted as accidental cougar fatalities were discovered while we were engaged in deer work. On September 8, 1951, in Dry Creek Canyon, Millard County, Gashwiler found the skull of a small cougar which had a piece of curlleaf mountain-mahogany wood (*Cercocarpus ledifolius*) penetrating the brain cavity (Plate I). The only part of the carcass found was the skull with the atlas attached; a coyote had probably carried it to the spot where found. From the weathering it was estimated the animal had been dead 2 or 3 years. The curlleaf mountain-mahogany stub was 81 mm. long, 24 mm. wide, and 15 mm. thick. It had entered the skull on the ventral side just anterior to the glenoid fossa through the right side of the basisphenoid, thence through the bulge of the posterior part of the frontal bone. The tip of the stub emerged a little ventral and posterior to the postorbital process of the frontal bone. Thus, the stub entered the right ventral side of the anterior brain cavity and undoubtedly caused the animal's death. Cougar hair still clung to the end of the stub where it had been wedged at the time of the incident. Because of weathering, no other hair remained on the skull.

Dry curlleaf mountain-mahogany wood is very hard, heavy, brittle, and so dense it will not float in water; in short, its characteristics adapt it admirably to withstand the type of stresses and strains attendant to the accident under discussion. Regardless of its qualities, it would take a strong force to drive a relatively blunt stub through the skin of a cougar's

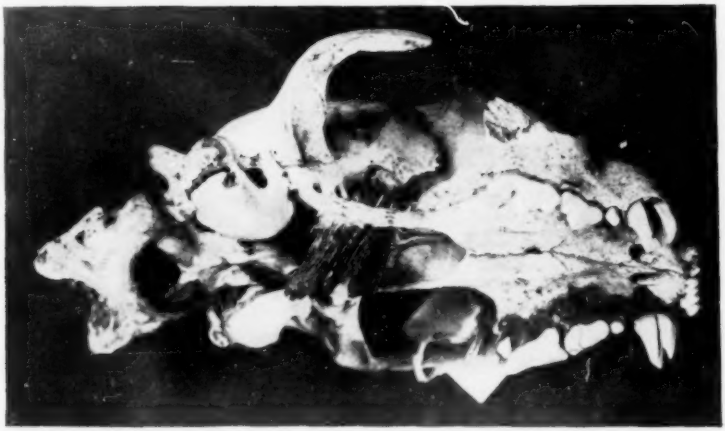

PLATE I

ABOVE: Skull of cougar with brain cavity pierced by a piece of curlleaf mountain-mahogany wood.

BELOW: Skeletons of a mule deer yearling doe (*A*) and a mature cougar (*B*) in Oak Creek Canyon.

throat, the base of its tongue, and two thicknesses of skull bone. The cougar must have been moving at a high rate of speed to develop sufficient force to impale itself in such a manner. It seems logical to assume that the cougar struck the stub during the violent action which characterizes its method of capturing large prey animals. Cougars frequently jump from relatively high places when treed by dogs and could thus impale themselves. However, this possibility was discarded because a close count has been kept of the cougar removals from this area and if such an accident had occurred during a cougar hunt, the hunters undoubtedly would have informed us.

The other cougar fatality was found by Robinette on June 15, 1950. He discovered the skeletons of a Rocky Mountain mule deer yearling doe (*Odocoileus h. hemionus*) and a large, mature cougar (undoubtedly a large male of the subspecies *kaibabensis*) lying beside each other near the head of Oak Creek Canyon, Millard County (Plate I). They were found in a grove of gambel oak trees (*Quercus gambelii*) from 3 to 6 inches in diameter, and were so close together there was an intermingling of their hair. Weathering of the carcasses was identical, indicating simultaneous deaths. From the dentition and pelage of the doe it appeared that the incident had occurred about a year earlier during late May or June, 1949.

Disintegration of the carcasses made accurate reconstruction of the accident difficult. However, it seems plausible that the lunging deer with the cougar hanging on could have collided with the oak trunks resulting in the death of both. The cougar's skull displayed no evidence of a fracture, but there was a separation of the atlas from the occipital condyles of the skull. Although the evidence is not positive, it seems logical to assume that the cougar died of a broken neck. This assumption is supported by evidence from the other fatality which had weathered for a longer period but still had the atlas and the occipital condyles firmly joined. Another plausible cause of death could have been poisoning, but as no poison had been used on the Oak Creek area and the deer carcass showed no signs of having been fed on, poisoning was discarded as a possible reason for the cougar's death.—Jay S. Gashwiler, *U. S. Fish and Wildlife Service, 307 Snell Hall, Oregon State College, Corvallis, Oregon;* and W. Leslie Robinette, *U. S. Fish and Wildlife Service, 444 Federal Building, Salt Lake City, Utah.* *Received April 9, 1956.*

PHOCOENOIDES DALLI WASHED ASHORE IN CALIFORNIA

On January 28, 1956, at Long Beach, California, the body of a Dall porpoise was found among the debris caused by recent rain storms. The animal had washed ashore during the night and had only been dead for a short time. It could not be determined whether the porpoise was stranded or wounded. There was a deep, fresh wound in the right side which may have been inflicted by a group of small boys playing with the carcass. The porpoise measured 7¾ feet from snout to base of tail notch, which is larger than existing available records for this species. Other measurements of the animal were as follows: height of dorsal fin, 6½ inches; axillary length of flipper, 8 inches; the maximum width across the tail flukes was 18 inches. The sex was not determined. The oval patch of white on the sides and a faded white patch on the dorsal fin were the only coloration. The rest of the body was a glossy black.

Existing records show that the Dall porpoise is relatively rare in California waters and data are too few to map its distribution with any degree of certainty. Records indicate that this mammal is a permanent resident of the Farallon Island (Yocom, Jour. Mamm., 27: 367–68, 1946). It has also be recorded for the Santa Barbara Islands (Benson and Groody, *op. cit.*, 23:41–42, 1942) and the Channel Islands (Lustig, *op. cit.*, 29:183, 1948).—Bernard B. Butterworth, *Department of Biology, University of Southern California, Los Angeles 7, California.* *Received February 10, 1956.*

REMARKS ON THE BIFID CLAWS OF THE VARYING LEMMING

One of the most frequently mentioned characteristics of the varying lemming (*Dicrostonyx*) is the growth of enlarged claws on the 3rd and 4th digits during the winter. Hinton (MONOGRAPH OF THE VOLES AND LEMMINGS [MICROTINAE] LIVING AND EXTINCT. London, p. 139, 1926) pointed out that in summer the claws do not differ greatly from those of other lemmings; but in winter "they are very large, sometimes exceeding half an inch in length, and have the appearance of being double, each of the two fingers seeming to bear two enormous claws, one on top of the other, which are separated at their tips by a more or less deep notch." It was formerly believed that the growth of bifid claws was a characteristic of only the "old lemmings in winter pelage." However, Degerbøl and Møhl-Hansen (Med. Om. Grønl. 131.):14, 1943) have pointed out that young born during the winter also develop bifid claws. In a captive colony of varying lemmings, *D. groenlandicus rubricatus* (Richardson), stemming from Umiat, Alaska, I find that adults, as well as young born during the winter, develop bifid claws regardless of their coat color, which may be white winter pelage, dark summer pelage, or various intermediate types.

Bifid claws develop in young and old animals in essentially the same manner. The first indications of winter claws are the enlargements of the toe pads of the 3rd and 4th digits. In young animals this is detectable when they are only ten days old and in old animals in the fall or early winter. The distal part of the toe pad then grows outward, hardens, and becomes cornified. The normal claw and the cornified toe pad grow longer and vertically deeper and are fused together, although deepened lateral grooves denote their boundaries. Anderson and Rand (Jour. Mamm., 26:301, 1945) stated that the normal claw was "separated" from the cornified toe pad "by a deep lateral groove." I find that they are so tightly fused together that they cannot be easily pulled apart. However, injury from being bitten on the toes when lemmings fight occasionally results in abnormal growths of the cornified toe pads (Plate 1).

As the claws are used for digging, the ends are worn away and the tip of each becomes "bifid" in appearance. Differential wear accounts for the notch between the normal claw and cornified toe pad.

Most authors agree that the bifid claws are replaced by (normal) summer claws in the spring but do not agree as to the precise manner in which it is accomplished. Hamilton (AMERICAN MAMMALS. McGraw-Hill, New York, p. 109, 1939) stated that ". . . the auxiliary claw is lost." Anderson and Rand (*loc. cit.*) stated that the claws become "normal in spring when the winter growth drops off." Cahalane (MAMMALS OF NORTH AMERICA. Macmillan, New York, p. 504, 1947) stated "They are shed (sloughed off) in April or May." Nelson (WILD ANIMALS OF NORTH AMERICA. Nat. Geogr. Soc., Washington, D. C., p. 166, 1930) said they were "molted in the spring."

Approximately 30 animals with bifid claws were examined at regular intervals in order to observe the precise manner in which the bifid claws are replaced by (normal) summer claws. At the beginning of the observation period (January 1) one animal had already gained summer claws although all of the others had bifid (winter) claws. A single bifid claw was pulled off the toe of three different individuals; this resulted in profuse bleeding of the exposed terminal skeletal joint. In each case the damage was sufficient (or later damage resulting from the digging activities of the individual was sufficient) to prevent the development of new claws. A claw was also removed from the 3rd digit of the animal with summer claws, with the same results.

In order to test whether or not the bifid claws grow after they are first formed, a notch was filed on both the dorsal and ventral surfaces of a bifid claw of a few individuals. As expected, the claws grew continuously and at the same time were worn off by the digging activities of the animals. One animal was housed in a container having smooth sides and bottom; its claws continued to grow and became abnormally long and twisted distally. As observations continued it was noted that the bifid claws became shortened (Plate I), and the toe pads failed to cornify.

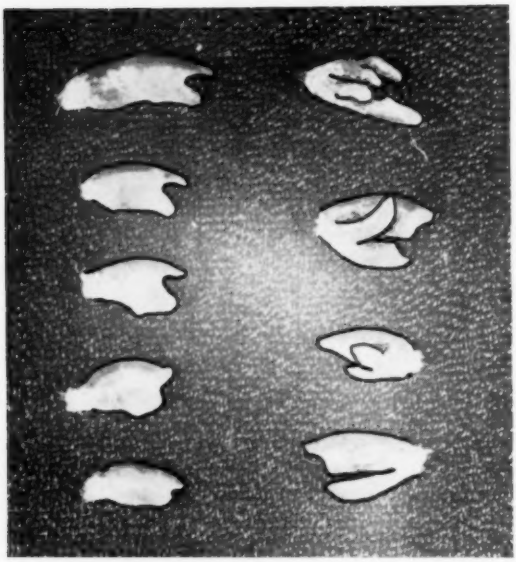

PLATE I

Bifid claws of the varying lemming. Column to left shows (top to bottom) the progressive wearing off of winter claws. Column to right shows abnormal growths of cornified toe pads as a result of injury.

The dorsal part (normal claw) continued to grow. Eventually, the cornified toe pad wears off completely, and the dorsal claw takes on the growth form of a (normal) summer claw. Records revealed that in each case the change from bifid claws to (normal) summer claws was accomplished by the gradual wearing away of the former, as influenced by differential growth between the claw and toe pad. The cornified toe pads did not drop off, slough off, nor was the bifid claw molted. It would appear to me that the bifid claws may be replaced in nature in the same manner as observed under laboratory conditions.—Richard M. Hansen, *Agricultural Experiment Station, Colorado Agric. and Mech. College, Fort Collins, Colorado.* *Received March 9, 1956.*

RENAMING OF *MINIOPTERUS AUSTRALIS MINOR* LAURIE & HILL

It has come to our notice that *Miniopterus australis minor* Laurie and Hill, List of Land Mammals of New Guinea, Celebes and Adjacent Islands, 1954: 72 is preoccupied by *Miniopterus minor* Peters, 1867, from Zanzibar. We now rename this race *Miniopterus australis shortridgei*. The type and paratypes are skins and skulls, not specimens in alcohol as listed.—E. M. O. Laurie and J. E. Hill, *British Museum (Natural History), Cromwell Road, London, S.W.7.* *Received February 8, 1956.*

SEXUAL BEHAVIOR OF TASSEL-EARED SQUIRRELS

I had an excellent opportunity to observe sexual behavior and copulation in the little-known northern tassel-eared squirrels, *Sciurus aberti ferreus*, on the west slope of Genesee Mountain, Jefferson County, Colorado, on March 31, 1956. The locality was at an altitude of 7900 feet in a forest of Douglas fir (*Pseudotsuga menziesi*) mixed with yellow pine (*Pinus ponderosa*). The weather was clear and still, the temperature in the 70's. My attention was first attracted to the squirrels at about 1:00 P.M. by their characteristic throaty chucking calls, and by the commotion they caused while running through the trees. I stalked to within 25 feet of the tree in which they were, and watched them for almost an hour and a half through 7 x 50 binoculars.

I counted at least nine squirrels in the immediate vicinity; five were in the black color phase, the other four were in the gray phase. It soon became obvious that one black male (sex was determined by the observation of well-developed scrotal testicles) was defending one particular sixty-foot Douglas fir from the intrusions of seven other squirrels (at least two, and presumably all, of which were males). The activities followed a fairly regular pattern. The intruding squirrels would invade the tree by crossing from the upper branches of adjacent trees. Once in the defended tree, the intruders would climb towards the top. The defending male would then chase them, often two at a time, until he had driven them out of the tree. Occasionally the intruding squirrels would scuffle briefly in the upper branches with the defending male before taking flight. These chases were much the same as those I have frequently observed in *Sciurus niger* and *Sciurus carolinensis*. The chases usually ended by the defending male driving the others down to the ground. The intruders would then sit quietly on the ground or on the lower branches of nearby trees. The defending male, who never left his tree, would then sit on a limb fifteen or twenty feet above the ground, with his tail arched over his back, barking continually and tapping the limb with his forefeet. The situation would remain thus for minutes at a time, until one of the intruders attempted to invade the tree again. The intruding squirrels would occasionally chase each other, when one approached another too closely.

After a while the defending male climbed to the very top of the fir and approached a squirrel of the gray phase which I had seen earlier, and which had remained quietly hidden in the dense foliage all the time. This was obviously a female, as the male mounted her from behind and copulated for less than 90 seconds. The female was clinging vertically, head uppermost, to the slender trunk of the tree. Copulation was accompanied by low, rather hoarse, mewing notes. This was interrupted by several of the other squirrels reinvading the tree; the defending male turned and drove them off again. Two of the black intruders eventually wandered away, travelling on the ground. When I left them at 2:30 P.M. the black male was still barking his warnings to the remaining five squirrels, who were waiting in adjacent trees.—DALE W. RICE, *U.S. Fish and Wildlife Service, Midway Islands, Territory of Hawaii, c/o Navy 3080, FPO San Francisco.* *Received April 9, 1956.*

ACORN CONSUMPTION BY CHIPMUNKS AND WHITE-FOOTED MICE

During the course of an investigation of factors affecting oak mast production, considerable attention was directed toward determining the biotic agencies responsible for the utilization of the fall acorn crop. Particular emphasis was focused on the possible influence of certain small mammals in competing with game animals for this food. In order to adequately interpret the extent of acorn competition, a controlled feeding study was initiated in mid-October, 1952, and continued to mid-November. Five wild eastern chipmunks (*Tamias striatus rufescens*) and four white-footed mice (*Peromyscus leucopus noveboracensis*) were live-trapped in the vicinity of East Lansing, Michigan, for use as test animals and confined in cages.

Four species of acorns, previously collected and examined for soundness, were the only

food available during the tests, and these were fed periodically depending upon the quantity of uneaten food remaining. During the aggregate 98 chipmunk-days of feeding, the average consumption was 6.1 acorns per animal per day, based on a total of 600 acorns eaten (Table 1). Only slight variations from this mean were noted; a high daily average of 6.8 acorns for one animal was probably the result of greater energy expenditure, since this animal had use of a rotary exerciser cage. The lowest individual consumption, averaging 5.3 acorns per day, appeared to result from a distaste for red oak (*Quercus rubra*) acorns rather than a lower food requirement.

It was soon evident that red oak acorns were not readily eaten. Therefore, during the second week in November no additional food was made available for a five-day period in order to encourage utilization of this species. These were subsequently eaten, except as noted above. No ill effects were noted, although Baumgras (Jour. Wildl. Mgmt., 8:296–300, 1944) reported that two of three fox squirrels died within ten days when fed this species. He believes the high tannin content of red oak is unpalatable for this animal. However, the writer observed that urban fox squirrels greedily consumed red oak acorns even though other highly preferred foods, such as corn and peanuts, were available.

All white oak (*Q. alba*) and black oak (*Q. velutina*) acorns fed were consumed, a total of 186 of each species. White oak acorns appeared to be more highly preferred since they were invariably eaten first whenever these species were fed together. Baumgras (*op. cit.*) noted a greater utilization of this species by fox squirrels, and believed this represented a lower food value for white oak acorns. From chemical analysis, he found acorns of white oak higher in water and crude fiber, and lower in ash, ether extract, and total digestible nutrients than any of the other foods tested; they also are low in protein.

Through the last five days of the experiment one lot of 30 scarlet oak (*Q. coccinea*) acorns was fed to each of four chipmunks. All but three of the total 120 acorns were consumed, yielding a daily average of 5.8 acorns per animal, which was only slightly below the total average. It would appear that scarlet oak acorns are comparable in palatability to black oak.

TABLE 1. — *Acorn consumption of captive chipmunks and white-footed mice*

FEEDING PERIOD (DAYS)	SPECIES AND NUMBER OF ACORNS								TOTALS		DAILY AVERAGE
	Red Oak		White Oak		Black Oak		Scarlet Oak*				
	Fed	Eaten	Fed	Eaten	Fed	Eaten	Fed	Eaten	Fed	Eaten	
Eastern Chipmunk											
2	6	3	6	6	6	5	—	—	18	14	7.0
28	48	48	57	57	57	57	30	30	192	192	6.8
23	29	28	41	41	41	41	30	30	141	140	6.1
23	31	29	41	41	41	40	30	27	143	137	6.0
22	30	5	41	41	41	41	30	30	142	117	5.3
98	144	113	186	186	186	184	120	117	636	600	Av. 6.1
White-footed Mouse											
4	3	0	3	2	3	3	—	—	9	5	1.2
1	3	0	3	1	3	1	—	—	9	2	2.0
28	15	2	21	21	20	20	12	6	68	49	1.8
28	15	4	20	20	20	20	12	10	69	54	1.9
61	36	6	49	44	46	44	24	16	155	110	Av. 1.8

* Sole diet for 5 days

Average consumption for the white-footed mice was 1.8 acorns per day, based on a total of 110 acorns eaten during an aggregate 61 days of testing (Table 1). White oak acorns were again preferred, but this preference may have been due to the softer testa of this species. Although a slightly higher proportion of black oak acorns fed were consumed compared to white oak, the latter provided considerably more food per acorn consumed. Because of their large size, red oak acorns presented a major problem. However, about half of these fed were breached and one-fourth to one-third of each endosperm eaten. In feeding, a small hole was gnawed at the base of the acorn and gradually enlarged to allow extraction of the food fragments. Due partly to this feeding difficulty a preference rating could not be established for red oak, although it appeared to be somewhat lower than that for either white or black oak. Consumption of scarlet oak was probably maximum for one individual, 2.0 acorns per day, but only 1.2 for a second animal; each animal was fed twelve acorns during a five-day period. Hamilton (Jour. Wildl. Mgmt., 5:399–341, 1941) stated that under natural conditions adult mice required about six grams of food daily; this is approximately equivalent to two white oak or three black or scarlet oak acorns.

Unfortunately, none of the specimens were weighed before the tests began; however, the examination of most animals at the termination of the diets did not indicate abnormal physical condition. It appeared that malnutrition did not result during the month-long feeding tests from a diet comprised solely of acorns.

Acorns provide highly nutritious food for numerous species of wildlife and therefore rate a position at the top of the food list, not only because they are preferred food items, but because they constitute a staple fall and winter food for many game animals. Acorns are not always abundant or available to game due to the irregular nature of oak mast production, and because of serious depredation by non-game wildlife. During a poor crop year the lack of food may prove critical to game species dependent upon this food for survival. Allen (Game Div. Pub. 100, Mich. Dept. Cons., 1943) noted a marked fox squirrel mortality, followed by a widespread reproductive failure, resulting from severe malnutrition accompanying an acorn crop failure in Allegan County, Michigan. Linduska (Game Div. Pub., Mich. Dept. Cons., 1950) observed a food shortage existing among sciurids in several Clinton County woodlots during an oak mast failure in 1940; this condition did not recur during the following two years, presumably due to an increased production of acorns. He believes no marked incompatability exists between woodland sciurids but observes that all are in direct competition for the same foods, and, except for chipmunks, the same nesting sites. Although the lesser sciurids are most detrimental in eliminating acorn mast otherwise available to game animals, Allen (*op. cit.*) believes the importance of mice as food competitors of fox squirrels has not been sufficiently recognized.

Assuming chipmunks and mouse densities of seven each per acre, the total number of black oak acorns consumed within sixty days of acorn fall is computed to be approximately 3,300 sound acorns per acre, or equivalent to about one-third to one-half bushel. This is exclusive of caching, which is undoubtedly great for these animals, nor does it include depredation by other wildlife species. The consumption of this quantity of food would amount to approximately one-fifth the total crop, since Downs (Jour. Wildl. Mgmt., 8:339–340, 1944) found an average production of acorns at between 14,000 and 16,000 per acre per year (apparently on the basis of a seven-year period) for southern Appalachian oaks. Fortunately, small mammal populations often fluctuate violently and low densities are common. The most serious consequences may result from concurrent high rodent abundance and poor mast years. During high acorn production years neither game animals nor oak stand regeneration will suffer, since the total acorn crop would probably not be consumed. The over-all effects of acorn consumption by non-game wildlife may be considerable and may act to regulate game animal populations through limiting range carrying capacity.

The writer gratefully acknowledges the valuable assistance of Dr. Leslie W. Gysel, Associate Professor, Department of Fisheries and Wildlife, Michigan State University, who supervised the study. Drs. C. T. Black, In Charge, Rose Lake Wildlife Experiment Station,

Michigan Department of Conservation, and Don W. Hayne, Associate Professor, Department of Fisheries and Wildlife, Michigan State University, provided the necessary facilities and materials for conducting the nutrition experiment.—Louis J. Verme, *Michigan Department of Conservation, Shingleton, Michigan. Received February 4, 1956.*

HOME RANGE OF *SYNAPTOMYS COOPERI*

During four years of extensive trapping in the Whiteshell Forest Reserve of eastern Manitoba, only five specimens of *Synaptomys cooperi cooperi* Baird have been recorded. One was taken in a snap-back trap. Three were taken in tumble-in traps but were drowned because of heavy rains during the trapping period. The fifth specimen was captured in a Sherman live trap, and was marked and released. Subsequently this animal was taken in five additional traps and was captured a total of seven times. The field work was carried out by Mr. C. D. Bird.

Since *S. cooperi* is a relatively rare animal in the study region, the prospect of ever determining sufficient ranges of the species to treat statistically is rather remote. Hence it was decided to report upon the home range of this specimen. Should an unexpected rise in the population of the species occur, further range records will be added.

The specimen in question, a subadult female, was first taken on August 20, 1955, and was found dead in one of the traps on August 26. The traps were set in the form of a grid with a 66-foot interval between them. Traps were examined both morning and evening, and the specimen was released twice in evening visits, indicating some daylight activity. The home range was found to be 0.8 acres using the boundary strip exclusive method or 1.0 acres using the inclusive boundary strip method (Stickel, Jour. Mamm., 35:1–15, 1954). This is equivalent to a cruising radius of 105 or 118 feet, respectively. The determined range lay entirely within the boundaries of the plot. This range may be used tentatively in computing the boundary strip for the species. The specimen measured 118, 14, 17 mm. and weighed 12.9 grams. The measurements of the specimens previously recorded were 115, 16, 17 (SA♂), 111, 15, 18 (P♀), 90, 11, 17 (SA♂) and 94, 17, 17 (SA♂). All specimens were taken in sphagnum bog habitats with tall black spruce and tamarack trees affording a relatively dense canopy.—C. H. Buckner, *Forest Biology Laboratory, Winnipeg, Manitoba. Received February 10, 1956.*

SEASONAL PERIODS OF SURFACE INACTIVITY OF THE POCKET GOPHER

An ecological study of the pocket gopher (*Thomomys talpoides tenellus* Goldman) made during the summer of 1952 in the Jackson Hole region of Wyoming revealed two periods of apparent inactivity of the gophers. One of the periods when no soil was brought to the surface of the ground was noted on the main floor of Jackson Hole (elevation 6,750 feet). This period was three to four weeks in duration, from the second week in August until shortly after the first week in September. Two plots had been previously laid out to measure the amount of soil brought to the surface by the gophers. Observations disclosed that only a very small amount of soil was brought to the surface of these plots during this period compared to the amount of soil in any similar period earlier in the summer. No soil at all was brought to the surface during the last week in August. Any breaks in the tunnels caused by horses were immediately repaired, however, showing that the gophers were not inactive, but that they were not bringing any soil to the surface of the ground.

Several authors have mentioned the late summer period of seeming inactivity. Miller (Jour. Mamm., 29:38–44, 1948) stated that the pocket gopher does little digging when the soil is hot and dry. Crouch (U.S.F. & W. Cons. Bull. 23, 1942) found that in late summer the gophers dig deeper because of increased surface temperature and decreased soil moisture. The soil excavated during this period is filled into unused upper tunnels and is not brought to the surface.

The other period of apparent inactivity was observed in the higher elevations above 8,500 feet on Big Game Ridge and other areas in the Teton Wilderness Area. This early summer period lasted from the time the snow melted off the south slopes in June until after the first week in July. On July 3 there were still deep snow banks on the north-facing slopes of Big Game Ridge, but the south-facing slopes were free of snow. There were abundant winter earth-cores on the south slopes but no new mounds had been formed since the snow melted. A week later a few new mounds had been formed and new mounds were added in all areas free of snow for the next three days. In addition to the formation of new mounds, numerous holes left open by winter burrowing activities were filled to ground level with fresh soil. Holes filled with soil were also observed in other locations in the Teton Wilderness Area during the same period of time. The author did not make any observations to determine if the previously mentioned late summer period of inactivity also occurred at the higher elevations.

The early summer period of inactivity was observed by workers of the U.S. Forest Service (Ann. Rept., Rocky Mt. Forest and Range Exp. Sta., 1943) in a cooperative gopher control experiment carried out jointly by the Rocky Mountain Forest and Range Experiment Station and the Fish and Wildlife Service in Grand Mesa National Forest, Colorado. They found that in areas above 10,000 feet there was no evidence of gopher activity until late July. They attributed this inactivity to the breeding season and to the birth and raising of young. This idea, however, accounts mainly for the inactivity of the females but not of the males during the whole period. The numerous holes filled with soil coinciding with the start of new mound formation on Big Game Ridge seem to indicate a need for an additional explanation for this period of seeming inactivity. It is possible that the gophers are actively burrowing during this period but are not bringing any soil to the surface. All soil displaced could be used to fill the shallow tunnels that were made when there was a covering of snow. When these unused tunnels are filled the soil would then be pushed to the surface and new mounds would become evident.

Lack of visible sign of pocket gopher activity may not mean that the gophers are completely inactive. Environmental factors or phases in the life history of the gopher may cause changes in the activity pattern, but they do not necessarily cause complete inactivity. Further research needs to be done at high altitudes on the early summer surface inactivity of the pocket gopher.—WILLIAM A. LAYCOCK, *University of Wyoming, Laramie, Wyo.* *Received March 9, 1956.*

DISTRIBUTION OF THE PORCUPINE IN CONNECTICUT

G. G. Goodwin, in his MAMMALS OF CONNECTICUT (State Geol. and Nat. Hist. Bul. 53, 1935), states that "the porcupine for many years has been practically unheard of in Connecticut. Formerly it was probably not uncommon in the forested mountain districts of the northwestern section of the state. . . Although there are no definite records to show that this animal is a native of the state, it seems more than probable that if all the leads were followed out, proof would not be wanting to establish its existence here." It was my purpose to pursue what leads could be found and to investigate the distribution of this animal in Connecticut. Survey letters were consequently sent to all State Foresters. Newspapers were scanned and many outdoorsmen personally interviewed. Every lead was followed up by field observation, if possible, to check its authenticity.

The accumulated data, entered on Fig. 1, are summarized as follows:

New Haven County: specimen captured in the West Rock Range, 1953, by George Whitney, D.V.M.; dog dequilled from New Haven area by Dr. George Whitney; dog dequilled from New Haven area by Dr. Salo Jonas.

Fairfield County: specimens, either found dead or captured alive, were seen and photographed on several occasions in the town of Sherman by the author.

Litchfield County: dens believed to be active, as evidenced by fresh scat and signs of porcupine feeding in the area, were seen at Salisbury, Roxbury, Cornwall, and Norfolk.

Specimens, either dead or captured alive, were seen by the author in the following localities: Salisbury, Falls Village, Kent, Norfolk, and reported by Ranger Carl Hubbell from Cornwall. Two specimens were shot by Dr. George Whitney near Winsted. Quills from dogs were seen by the author in New Milford and reported to him from Cornwall by Ranger Hubbell. Quills in a young raccoon were removed by Harry Williams, First Selectman, in Colebrook and reported to the author. Ranger A. J. Brooks reported "heavy populations, heavy feeding in large plantations, and evidence of gnawing on dwellings in Colebrook."

Hartford County: Ranger Brooks reported the same for Hartland and added "medium population, evidence of gnawing on one dwelling and on several wooden outhouses in Barkhamstead."

Tolland County: several active and long standing dens were seen by the author in the Bigelow Holland-Mashapaug Pond area. Embryos from the females of 45 porcupines trapped in the Mashapaug Pond area are in the University of Connecticut Zoology Collection. They were collected in 1947 and 1948 by Mr. Alfred Migneault. Damage to a large plantation in West Willington was reported by Ranger Gordon Abbott.

Windham County: a study skin, No. 308 RMW, from Chaplin, is in the University of Connecticut Zoology Collection; the specimen was shot by Lionell Robitaille, December 12, 1953. Skull only, No. 301 RMW, 1 mi. N. Westford, was collected by Steve Supina.

It would appear that the porcupine is not uncommon in areas of both the western and eastern uplands. The porcupine, at present, appears to be absent from the lowlands regions of the central valley and from southeast Connecticut. The implication is of a northern invasion route through the split upland masses of southern New England, the Connecticut River serving as a barrier south of north central Massachusetts.

The animal, at present, seems to be most successful where there is ledge and mixed conifer-hardwood forests relatively free from intense human competition for the land. Goodwin has stated that "formerly it (the porcupine) was probably not uncommon in the forested mountain districts of the northwestern section of the state." It should be added

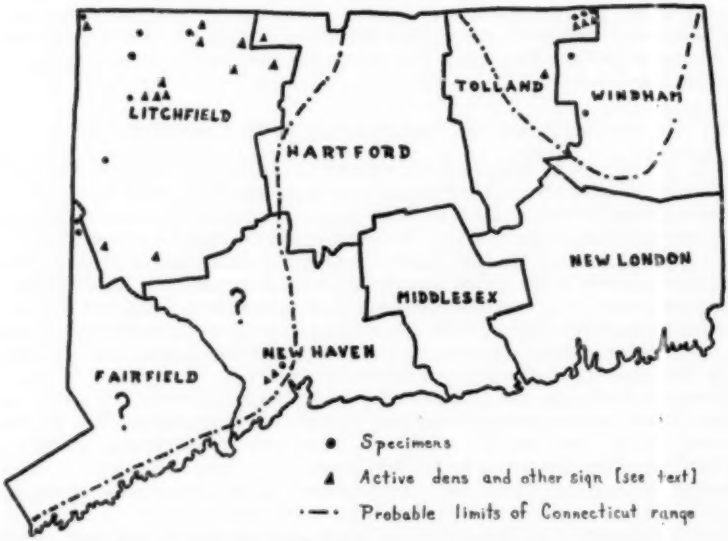

FIG. 1.—Distribution records and probable range of the porcupine in Connecticut.

that the animal probably occurred in the northeastern section also, as it does today. I believe we can further postulate that the porcupine retreated with the spread of intensive agriculture in the state and the consequent destrucion of its habitat through cutting, burning, and grazing. Its re-establishment is largely dependent upon the purchase of many marginal farms by urban people who sought seasonal or permanent escape from the pressures of city life and who, seeking seclusion, actively encourage a return of the forest cover and the wildlife. Spencer (Trans. N.A. Wildl. Conf., 11, 1946) also stated that in many areas the porcupine has adapted well to agricultural regions where there are many small farm woodlots and orchards. This is certainly descriptive of much of Connecticut's agricultural lands and is undoubtedly another major factor in the re-establishment of the porcupine in this state.

Spencer (*op. cit.*) also claims that the porcupine is increasing its populations despite its low biotic potential due to the man-made food supplies and the reduction of natural enemies. While there is no doubt that the Connecticut population is increasing for these same reasons, it appears unlikely that the porcupine will extend its range much further south in the eastern sector of the state. However, in the western section its range may be further expanded although its numbers will be limited due to the highly urban and suburban land use pattern.

Several reports of porcupine damage to pine plantations were received. Examination revealed no toothmarks or porcupine scat in the area, but only dead trees with patches of bark missing due to fungus and insect invasion. Tall trees could not be closely examined and it is possible that earlier porcupine damage created invasion points for insects and disease. Close examination of smaller trees would not indicate this, however. It appears to be mistaken identification of the cause of damage. Feeding in large plantations in West Willington and Colebrook is reliably reported, but nowhere has the author seen areas of concentrated feeding, with large numbers of trees completely stripped, such as he has seen in northern New England and the Adirondack Mountains of New York. Most of the feeding observed in Connecticut was the clipping of twig tips, largely hemlock, and young sprouts. Only occasionally was the stripping of a small area of some tree observed, and this was usually large-toothed aspen (*Populus grandidentata*). Some gnawing on cottages and outbuildings was observed, but nothing of importance, and there were several cases of quilled dogs; but the porcupine presents no serious economic problem at present although it appears quite certain that it is here to stay, expanding in numbers and in range.

I would like to express my appreciation to Dr. Ralph M. Wetzel of the University of Connecticut Department of Zoology for his aid and encouragement throughout the preparation of this manuscript.—CHARLES E. ROTH, *Department of Zoology, University of Connecticut, Storrs.* *Received February 22, 1956.*

MAMMAL REMAINS IN PELLETS OF COLORADO BARN OWLS

Literature references to the food habits of the barn owl (*Tyto alba pratincola*) in eastern, mid-western and Pacific regions of the United States are many, but since no records of small mammals utilized by this bird in the Rocky Mountain region were noted, the following may be of interest. In the autumn of 1953, 275 owl pellets were collected from an excavation four miles southwest of Fort Collins, Larimer County, Colorado. Several owl burrows were found in the vertical walls of this pit. The number of owls and length of time during which these burrows had been inhabited is not known, but two birds were seen simultaneously and the carcass of a third was found.

Pellets ranged in weight from 3.0 to 16.9 grams and averaged 6.0. The number of skulls per pellet varied from one to seven. One thousand and eighteen skulls taken from the 275 pellets were identified as follows: *Microtus ochrogaster*, 288; *Peromyscus* sp., 266; *Microtus pennsylvanicus*, 157; *Reithrodontomys* sp., 108; *Perognathus* sp., 65; Mammal too fragmentary for identification, 49; *Mus musculus*, 36; Passerine birds, 33; *Sylvilagus* sp., 11; *Rattus* sp., 2; *Dipodomys* sp., 2; and *Neotoma* sp., 1.

Crushing of the occipital and parietal bones was the most common damage to this group of skulls. In any one pellet both members of paired bones could usually be located, perhaps indicating that each pellet is the remnants of a particular meal. Figures above are conservative as "odd" bones were not enumerated.

Studies of Barn Owls in California (Hawbecker, Condor, 47:161–165, 1945) and in Michigan (Wallace, Mich. Agri. Exp. Sta., Tech. Bull., 208:1–61, 1948) indicated that prey was taken on the basis of availability.

The strongly nocturnal hunting habits of the barn owl are reflected by the absence of remains of diurnal mammals such as the least chipmunk (*Eutamias minimus*), rock squirrel (*Citellus variegatus*), thirteen-lined ground squirrel (*Citellus tridecemlineatus*), and blacktailed prairie dog (*Cynomys ludovicianus*), all of which were known to occur in the immediate vicinity.—Edward B. Reed, *Department of Biology, University of Saskatchewan, Saskatoon, Canada.* *Received February 3, 1956.*

COPROPHAGY IN THE COTTONTAIL RABBIT

Coprophagy was recently reported for the swamp rabbit (*Sylvilagus palustris paludicola*) by Hamilton (Jour. Mamm., 36:303–304, 1955). He indicated that the reingestion of droppings probably is more widespread in lagomorphs than is generally recognized. He also stated that cursory examinations of the stomachs of many cottontails (*S. f. mearnsii*) failed to indicate refection in that species. Meyers (Aust. Jour. Zool., 31:366–345, 1955) reported that coprophagy is a normal feature in the biology of the rabbit (*Oryctolagus cuniculus*) in Australia.

Since coprophagy in the cottontail rabbit apparently has not been reported the following observation seems noteworthy. On December 19, 1955, at the Kellogg Station of Michigan State University near Battle Creek, twenty-two rabbits were collected by shooting. Five of these had quantities of fecal pellets in the cardiac portions of their stomachs. The whole, tan-colored pellets were lying on top of well chewed "natural" foods that occupied the pyloric part of the stomach. The fecal pellets were positively identified by the presence of unsporulated coccidia oocysts and many rod-shaped bacteria.

Myers (*op. cit.*) reported that refection is important in nutrition and in vitamin economy and was most prevalent when food was scarce. The coprophagy reported here occurred when the ground was covered by snow which made green food unavailable. This may have created a situation in which coprophagy was likely to occur.—Aelred D. Geis, *Departments of Zoology and Fisheries and Wildlife, Michigan State University, East Lansing, Michigan.* *Received April 28, 1956.*

NORMAL BLOOD CELL COUNTS FOR THE COTTONTAIL RABBIT

During a study of the effects of certain pathogens on cottontail rabbits (*Sylvilagus floridanus*) it became necessary to know normal blood cell counts for this species. Rabbits were secured for this purpose by live trapping during the spring and fall of 1953, 1954 and 1955 at the Kellogg Station of Michigan State University near Battle Creek, Michigan. Counts were made on full grown and apparently healthy animals, using standard procedures. Blood was obtained by venipuncture of the peripheral vein of the ear. Twenty-eight white blood cell counts ranged from 4,350 to 11,000 per cubic millimeter with a mean of 6,736 and a standard error of ± 155. Sixteen red blood cell counts ranged from 4,520,000 to 7,700,000 cells per cubic millimeter with a mean of 5,817,500 and a standard error of $\pm 240{,}018$. Mean white and red blood cell counts in the domestic rabbit (*Oryctolagus cuniculus*) are 7,900 and 5,600,000 respectively (Runnells, Animal Pathology, Ia. St. Col. Press., Ames, 1946). Thus in the wild cottontail rabbit it appears that erythrocyte counts are about the same as in the domestic species while leucocyte counts are possibly lower.—Aelred D. Geis, *Departments of Zoology and Fisheries and Wildlife, Michigan State University, East Lansing, Michigan.* *Received April 28, 1956.*

BODY TEMPERATURE IN THE EASTERN COTTONTAIL

Over a twelve-month period I obtained 169 records of the body temperatures of cottontails, *Sylvilagus floridanus*, which had been live-trapped, captured by hand, or shot. These temperatures were obtained rectally with a standard clinical thermometer that has been certified by the U.S. Bureau of Standards. The only published information on body temperature in the cottontail that I am able to find is that of Petrides (Jour. Mamm., 28: 400–401, 1947) who found that the average body temperature of 14 cottontails kept in captivity was 101.6° F.

All of my temperature records were made on free-living individuals in Douglas County, Kansas. On the live-trapped individuals, temperature was recorded in the first three minutes that the animal was handled. On killed individuals the thermometer was inserted within ten seconds after the animal was shot. Two two-minute readings were made in quick succession, the second reading averaging about 0.3° F lower than the first. Body temperatures of killed individuals were measured while the air temperature was between 70° and 90° F. Measurements on live cottontails captured by hand, all of which were less than three months of age, were made immediately after the animals were caught.

All animals whose body temperatures were recorded were thought to be normal physiologically, with the exception of one animal obviously in shock, which died five minutes after the body temperature (92° F) was recorded.

In 77 live-trapped females, average body temperature was $103.7 \pm .11°$ F, and in 62 live-trapped males it was $103.3 \pm .17°$ F. Body temperatures of the freshly killed individuals averaged the same, $103.7 \pm .20°$ F for thirteen females and $103.3 \pm .25°$ F for eleven males. With hand-captured individuals, which were all less than three months old, four males averaged $103.5 \pm .30°$ F and two females averaged $103.1 \pm .11°$ F. The average range of normal body temperature is 102.0° to 105.5° F.

Except in the young that were hand-captured, the females average 0.4° F higher than the males. This difference is statistically significant. Increased metabolism in the oestrous and pregnant females possibly affects the body temperature, but the range of variability is higher in males than in females. Temperatures of hand-captured young individuals differed from those of adults. Three possible reasons for the difference are as follows: (1) the sample may not have been large enough to show the true value of temperature in the young cottontails, (2) techniques of measurement in young individuals may not have been accurate because of the difficulty of inserting the bulb of the thermometer into the rectum, (3) young individuals may differ from adults in body temperature.

No correlation was found between the body temperature and air temperature. Seemingly no correlation existed between the body temperature and the length of time the animal was in the trap; nevertheless the body temperature will rise as much as 1.5° F above normal if the animal is handled more than ten minutes. Therefore body temperature should be measured immediately after animals are removed from live-traps.—DONALD W. JANES, *State Biological Survey, University of Kansas, Lawrence.* *Received February 15, 1956.*

NEWBORN YOUNG OF A CAPTIVE MANATEE

Some information has been gleaned earlier from the births of two captive Florida manatees on the adaptation of its early behavior to aquatic environment, and what services its phlegmatic maternal parent performs for it (Moore, Jour. Mamm., 32:26, 1951). It is now possible to add some further bits to this partially composed picture from another baby manatee, *Trichechus manatus latirostris*. It was born November 1, 1955, at Ojus, Florida, to a ten-foot, four-inch adult which had been taken locally several weeks earlier for exhibit in an admission zoological garden called Tropical Panorama. This birth was unobserved, and may have occurred any time from 5:00 P. M. October 31st until shortly before the baby was discovered about 9:00 A. M. the next day. The placenta was only partly discharged at the time of discovery, and this may suggest that the calf was no more than a few hours old then. At the same time, however, it was definitely swimming under its own power, and the mother was not observed to assist it in any way, whereas the mothers did in the two cases of newborn earlier reported. It is interest-

ing that from the time of its discovery, the newborn young stayed down well beneath the surface of the water except for coming up periodically to breathe, and this is in agreement with the reports of the two earlier cases after the first few postnatal hours, although in both of those the adult took its young to the surface.

This mother manatee, like at least one of those earlier reported, flouted the legendary description of holding the babe in a maternal flipper embrace as it suckled at one of the pectoral mammae (recently illustrated on page 143 of Zim and Hoffmeister's MAMMALS, A GUIDE TO FAMILIAR AMERICAN SPECIES, 1955, Simon and Schuster). It merely lay horizontal in the water, belly down, feeding or drowsing while the baby helped itself to a teat under water as best it could. Something not previously clear about newborn baby manatees, but observed in this case, is that during its first several days this one swam entirely with its flippers, and only gradually and awkwardly during the first weeks did it learn to use its tail in swimming. This ties in rather well with the report of the one (Barbour, Jour. Mamm., 18:106–107, 1937) born with the tail folded against its venter, like that of a crawfish, so that it did not even straighten out for four or five hours after the birth.

This young manatee was not observed to link flippers with its mother and swim about the small exhibit pool with her thus, as one of the earlier reported captive babies had done in a much larger pool. It did ocasionally ride on its mother's back, definitely holding on as best it could by attempting to embrace her large body with its flippers. It swam beneath its mother's body to a considerable extent. Neither was observed to rest in the bowed position of repose, but in the case of the adult this could be because the exhibition tank was physically too shallow. For all of the above information upon the manatee baby at Tropical Panorama, the writer is indebted to Mr. Fred Hargreaves, the intelligent and keenly interested keeper of these animals, who captured the mother sea cow and took care of her from the beginning.

At the time of the writer's visit to Tropical Panorama, the manatee calf was 38 days old. Even at this age, however, it ate several lettuce leaves while I watched. In the exhibit tank, which was about 20 feet in diameter and was filled to a depth of about 3 1/2 feet, the baby manatee did not keep station with its mother but moved about freely in the whole area of the tank. With the permission of manager M. A. Dounay, Hargreaves let the water out of the exhibition tank and then obtained measurements as the writer called for and recorded them. These proved to be, for the mother and young respectively: total length (straight line), 124 and 52 inches; greatest width of tail, 28 and 13 inches; length of flipper, 13 1/2 and 8 inches; greatest width of flipper, 6 1/2 and 3 1/2 inches. On the calf only, we obtained: navel to genital aperture, 2 1/2 inches; genital aperture to anus, 12 inches. The Miami Aquarium babe weighed 63 pounds and measured 39 inches in length, presumably soon after birth (Barbour, *op. cit.*). After lifting the Tropical Panorama one in a net, we agreed that it must weigh about seventy pounds. It was a male and apparently in very good health, quite unlike the extremely emaciated one recently used to illustrate Bourliere's MAMMALS OF THE WORLD, Knopf, 1955, p. 211.

When the water was running out of the pool, the adult stirred about in a vaguely frightened manner, but seemed remarkably incapable of expressing visually detectable emotion over what should have been for it a very disturbing situation. When the water level dropped to about nine inches, and the sea cow was well stranded, she tried without any particular success to move forward with a humping motion like that of a phocid seal, raising herself on flippers knuckled under at the front end, and hitching forward at the rear on the flat of the tail pressed down. In nine inches of water over a mud bank, she could probably have made some progress, but it seemed quite evident that on level, dry land she would have been entirely helpless. As the adult gave up this effort, the young one tried to worm its way under her, and she made several efforts to cover the babe with her body as if to protect it. Hargreaves anticipated this, however, and prevented her from crushing the calf by pulling it away. In view of the extreme degree of adjustment to buoyant aquatic life, it is perhaps not surprising if the adult manatee should display no strong instinct to avoid crushing its young when stranded.—JOSEPH CURTIS MOORE, *Department of Mammals, American Museum of Natural History, New York.* ***Received March 3, 1956.***

LIVE AND DRESSED WEIGHTS OF AMERICAN BISON

The American bison herd on the Wichita Mountains Wildlife Refuge, Comanche County, Oklahoma, was established in 1907 by the donation of fifteen animals from the New York Zoological Park. The herd has increased to 922 animals as of January, 1956. During the years 1917 to 1954 inclusive, 1,847 bison, alive or butchered, have been sold or donated. The herd ranges over 59,000 acres of fenced range and is not fed hay or concentrates.

TABLE 1. — *Live and dressed weights of American Bison*
(Fall, 1953 to January, 1956)

AGE IN YEARS	AVERAGE DRESSED WEIGHT (LBS.) (WT.-RANGE)	NO. OF ANIMALS WEIGHED	AVERAGE LIVE WEIGHT (LBS.) (WT.-RANGE)	NO. OF ANIMALS WEIGHED	PER CENT OF YIELD
		BULLS			
1	370	1			
2	459(393-518)	36	865(795-995)	18	53
3	504(425-580)	49	968(945-1150)	24	52
4	616(383-775)	22	1163(925-1300)	8	53
5	680(531-827)	11	1138(895-1315)	6	60
6	689(596-899)	13	1273(1015-1590)	3	54
7	789(779-798)	2	1525	1	52
8	784(672-897)	5			
9	870(811-929)	2			
10	811(788-834)	2			
11	799(738-869)	3			
12	821	1			
14	743	1			
Total Animals Weighed		148		60	
		COWS			
1	329	1			
2	468(431-534)	7	930(876-985)	2	50
3	472(408-538)	13	858(820-990)	8	55
4	482(421-547)	25	891(850-950)	11	54
5	476(429-530)	11	877(800-945)	6	54
6	500(453-557)	8	862(857-870)	3	58
7	500(461-542)	4	930	1	54
8	520(484-557)	7	949(940-1020)	6	55
9	524(457-590)	2	945	1	55
11	469(467-471)	2			
12	473(434-500)	4	872(800-910)	4	54
Total Animals Weighed		84		42	

Table 1 shows the relation of live to dressed or butchered weight in pounds. Dressed weight is herein used as the weight of the meat, fat and bones of the four quarters minus the hide, head and entrails. The per cent of yield is figured as the ratio of dressed weight to live weight. The ages of the animals were determined from their brands. All bison on the Wichita are branded as calves with the year of their birth.

The heaviest bull, six years of age, weighed 1,590 pounds; the heaviest cow was eight years old and weighed 1,020 pounds. The average yield for both sexes is 54 per cent of the live weight.—ARTHUR F. HALLORAN, *Fish and Wildlife Service, Cache, Oklahoma.* *Received February 7, 1956.*

ABNORMAL DENTITION IN WHITE-TAILED DEER

Observations of several cases of abnormal dentition in white-tailed deer are described in this paper. Standard terminology is used as reiterated and clarified by Riney (Jour. Wildl. Mgmt., 15:99–101, 1951).

In specimens 106 and 107 (both from the same animal) seven teeth can be clearly seen in each mandible. On close examination of these teeth the first and second (from the diastema) have all the characteristics of P^2 and P^3. The third and fourth are identical in structure and closely match P^4 in comparative material. The fifth, sixth and seventh are normal examples of M^1, M^2 and M^3, This situation suggests a duplication of P^4 rather than the presence of a primitive P^1. This conclusion has been confirmed after examination of the specimens by Cowan (personal communication, 1951). A second case of this abnormality was observed later.

These specimens were found during the preparation of Nova Scotia material for demonstration mounts. The same collection provided two single jawbones (from different animals) in which P^2 was absent. We could not locate matching jawbones for either specimen so they may represent examples of traumatic damage at a very early date rather than the effect of genetic variation.

On November 21, 1953, in Queens County, N. S., an adult buck was noted to possess small but strong and well-formed "eyeteeth" on the upper jaws. They protruded from the gums to the extent of approximately 3/8 inch. The dentition of this specimen was otherwise normal. At the time of this observation the writer was accompanied by a Forest Ranger who later obtained the head of this specimen and observed a second case of the same abnormality at the same hunting camp. This specimen shows the shallow rooting of these teeth. The centers of the sockets are 1 1/2 inches from the anterior surface of the anterior molar. Their shape precludes any suggestion of molariform teeth and since they do not occur on the premaxillae, but on the maxillae, they cannot be considered as incisiform. It would appear justifiable to describe these teeth as true canines.—D. A. Benson, *Department of Lands and Forests, Halifax, Nova Scotia. Received February 6, 1956.*

SOME ADDITIONAL MAMMAL RECORDS FROM KENTUCKY

Recent mammal collecting in Kentucky has resulted in the acquisition of a few specimens of some species whose distribution in the state is poorly known. In an effort to bring up to date the knowledge of these species in the state, the literature has been surveyed and data pertinent to the specimens appended. Credit is due to The Research Fund Committee of the University of Kentucky for financial assistance in the collection of certain of the specimens; Charles O. Handley of the United States National Museum for verifying my identification of the specimens of *Corynorhinus* and for other courtesies; and to many of my students for assistance in the field.

Nomenclature of *Corynorhinus* follows that of Handley (Jour. Wash. Acad. Sci., 45(5): 147–149, 1955), wherein *C. rafinesquii* = *C. macrotis*, and *C. townsendii* = *C. rafinesquii*. Most of the specimens are deposited in the zoological collection of the University of Kentucky; a few are in the United States National Museum. Measurements are expressed in millimeters; averages are given first, followed by extremes in parentheses.

Lasiurus cinereus cinereus (Palisot de Beauvois)—There is little doubt that the hoary bat migrates across Kentucky. Miller and Kellogg (U.S. Nat. Mus., Bul. 205, 1955) imply that it does not breed in Kentucky. In this respect, the record of Bailey (Amer. Midl. Nat., 14:385–635, 1933) is of particular interest. He stated, "In June of 1929 Giovannoli found an old female hoary bat in a back yard at Lexington, Kentucky, with two small young clinging to her body. . . They were turned over to Doctor Funkhouser of the University of Kentucky." An adult female hoary bat with two young, in alcohol, is in the collection at the University of Kentucky. No data accompanies them; probably they are the individuals mentioned by Bailey.

At dusk on April 9, 1955, I shot an adult female hoary bat as she flew over a path along a patch of woods some two miles south of Beulah, Hickman county, Kentucky. There are apparently no other records of this species in the state.

Corynorhinus townsendii virginianus Handley.—Bailey (*op. cit.*), referring to the Mammoth Cave region, stated that this species "occurs in the general region, but specimens were not taken at the caves." Welter and Sollberger (Jour. Mamm., 20:77–81, 1939) took one individual from Carter Caves, in Carter County. They do not so state, but no skin was prepared from this individual. Dr. Welter informed me that the bat escaped a few moments after it had been captured and identified.

On October 12, 1952, I took an adult male and female from a cave at Natural Bridge State Park, in Powell county. They were hanging singly from the roof of the cave, some distance beyond the lighted zone at the mouth of the cave. Measurements are: total length, 100.5 (100-101); tail, 42.5 (40-45); hind foot, 11 (11-11.5). These are apparently the only specimens from the state.

Corynorhinus rafinesquii Lesson.—Garman (Bul. Essex Inst., 26:1-63, 1894) mentioned a specimen from Bowling Green (Warren county), collected by Miss Sadie Price. Hamilton (Jour. Mamm., 11:306-311, 1930) recorded a specimen of *C. r. rafinesquii* from Breathitt county. According to Charles O. Handley (personal communication, 1956) this specimen was misidentified, and "actually is the *C. macrotis* of other authors." Thus the specific name, originally applied in error, is now correct.

On June 14, 1955, a breeding colony of these bats was discovered in the attic and storerooms of a large log building at the Robinson Recreation Camp near Noble, Breathitt county. Five adults, all females, were collected between June 14 and June 22. All of them were lactating; their measurements are: total length, 106.8 (103–109); tail, 48.8 (46–52); hind foot, 12.8 (12–13). On June 22, seven juveniles were taken as they clung to the walls of the building. They were hanging singly, some accompanied by adults, some not. None of them were able to fly. Their measurements are: total length, 66.1 (60–74); tail, 26 (22–32); hind foot, 11.1 (11–11.5); humerus, 28.3 (24–35).

Oryzomys palustris palustris (Harlan).—Goldman (N.A.F. No. 43, 1918) reported three specimens from Barbourville, and indicated this race to range across southern and western Kentucky. Handley (personal communication, 1956) took a small series in Trigg county, and deposited the skins in the collection of the Museum of Zoology at the University of Michigan.

I took three specimens from a swampy field some two miles south of Beulah, Hickman county, on April 10, 1955. Measurements are: total length, 231.7 (223–245); tail, 109 (103–114); hind foot, 29.3 (28–31). One of the specimens is a female; she was pregnant, with one 27 mm. and one 23 mm. embryo.

Spilogale putorius (Linnaeus).—Welter and Sollberger (*op. cit.*) listed this species from Rowan and adjacent counties, and stated, "This species has not been encountered in the county by either of the writers; but fur dealers speak of a small spotted skunk which is sometimes taken." According to Larry Gale, of the Kentucky Department of Fish and Wildlife Resources, fur buyers from the southeastern mountains and from extreme western Kentucky regularly report the purchase of a few "civet cats." Mr. Ledford Perry, a fur buyer at Creekmore, McCreary county, furnished me with a cased skin of this species. According to Mr. Perry, the animal was taken in January, 1956, by a Mr. Clifton Douglas. —Roger W. Barbour, *Department of Zoology, University of Kentucky, Lexington, Kentucky.* *Received February 24, 1956.*

REVIEWS

Harper, Francis. THE MAMMALS OF KEEWATIN. Univ. Kansas. Mus. Nat. Hist. Misc. Publ. No. 12. 94 pp., 6 pl., 8 figs., 1 map. October 26, 1956. Price 75c (paper3 from Arctic Institute of North America, 1530 P Street, N.W., Washington 5, D.C.

This is the eleventh in a series of biological papers resulting from the Nueltin Lake Expedition to southwestern Keewatin District, Northwest Territories, Canada, in 1947. The work was sponsored by the enterprising Arctic Institute, under arrangements with the Office of Naval Research, and publication was aided by the National Science Foundation. The University of Kansas Museum of Natural History also is to be commended for helping to make available another attractive and informative publication at a reasonable price.

To the author, these pages must recall a pleasant and busy six months spent at the Windy River post with the Schweders, and with Anoteelik and Rita, among others. To the reader, they bring a refreshing breath of northern air from the vast and lonely Barren Grounds; a picture of the varieties and numbers of mammals which populate that broad belt of mixed forest and tundra, at the junction of the Hudsonian and Arctic life zones, stretching some 900 miles northwest from Hudson Bay to Great Bear Lake. This is a country of gently rolling contours, of much water, of stunted trees punctuating the expanse of low-growing vegetation, of occasional cliffs or talus slopes and numerous lichen-covered boulders. These features are briefly described in the Introduction, together with mention of earlier investigations by Preble, Seton and others, and remarks on comparative abundance of species.

The bulk of the text is devoted to discussion of the 34 species of mammals in the Keewatin District. Under each are included notes on life history, taxonomy, ecology, local distribution and economic relations, and a brief summation, from earlier literature, of distribution in adjacent regions. Most space is accorded to the Wolf and here we find a graphic description of the low-pitched, musical howl of this creature, heard mainly in the winter. Red Squirrels in the Windy River area were strangely silent and secretive during the summer; it is suggested that this odd behavior may be related to the lack of proper trees for shelter and vantage points. The most abundant mammal in the region, as well as the least restricted by habitat preferences, was *Clethrionomys;* it shared the muskegs with *Phenacomys* and the buildings with *Microtus.* Several records are cited of freshwater seals (probably *Phoca vitulina*) in the Thlewiaza River, outlet of Nueltin Lake.

A supplement lists 13 additional terrestrial mammals recorded from the district. There is appended a systematic list of ectoparasites (15 mites, 3 lice, 5 fleas) from southwestern Keewatin, with records of mammalian hosts. A bibliography of 99 titles and an index complete the volume. The attractive cover features a striking picture, by Earl L. Poole, of a Tundra Wolf watching the approach of a band of Caribou.—RICHARD H. MANVILLE.

Makepeace, Laura I. RABBITS, A SUBJECT BIBLIOGRAPHY. Spec. Biblio. No. 3, Bibliographical Center for Research, Rocky Mountain Region; pp. xii + 81, multigraphed, 1956. Price $2.00 from Denver Public Library, Denver 2, Colorado.

A vast amount of material is packed between the covers of this thin tome, including 3,485 entries, some of them duplicated under more than one of the 600 or so major subject headings. The compiler, not a biologist, is executive librarian emeritus at Colorado A & M College. She has conveniently provided a list of subjects, an index of the 2,500 or more authors, and a list of abbreviations of the nearly 500 periodicals cited. She lays no claim to completeness, and one misses reference to *North American Fauna, Science, Ecology* and other journals, as well as to any standard book. The listings were apparently gleaned largely from indexes and abstracting journals, concentrating on the "more modern period, ending in 1955." As here treated, "rabbits" appear to include most of the lagomorphs. Despite its shortcomings, this bibliography provides a splendid starting point for investigators on this group. Similar works for other members of our fauna would be most welcome.—RICHARD H. MANVILLE.

Dahlberg, Burton L. and Ralph C. Guettinger. THE WHITE-TAILED DEER IN WISCONSIN. Technical Wildlife Bulletin No. 14, Wisconsin Conservation Dept., Madison. 282 pp., illus., 1956.

This well-organized volume summarizes the investigations under Pittman-Robertson Project W-4-R from 1941 through 1954. Designed for consumption by technician and layman alike, it is written in a lucid and entertaining style and is embellished with many halftones, tables, maps and graphs. The authors "tried to include enough data to substantiate our conclusions, but . . . not to load the text with too many unimportant statistics." They have struck a nice balance, incorporating such technical data as are essential for developing and implementing sound management practices.

The text comprises nineteen chapters, arranged in four parts: (1) a brief review of historical factors affecting deer in Wisconsin; (2) the deer herd, with consideration of life history, movements, food habits, natality and mortality factors, and other topics; (3) problems of the deer range, perhaps the most important aspect of the study; and (4) deer management problems of various sorts. An Appendix of twelve parts, with data on how to age deer (by teeth), diseases and parasites (12 general sorts), browse species (110 trees and shrubs, with preference ratings), and other local material completes what should be a most useful aid to all those concerned with deer management, particularly in the Lake States area.—RICHARD H. MANVILLE.

Palmer, Ralph S. and E. M. Reilly, Jr. A CONCISE COLOR STANDARD. 8 pp., with colored center spread. Privately printed [A.O.U. Handbook Fund], Albany, N.Y., October 19, 1956.

This paper deserves to be called to the attention of mammalogists involved in color designations. Although prepared primarily for ornithologists, it is in part an answer to Davis' plea (Jour. Mamm., 37: 269–271, 1956) for an adequate color standard. It is intended as a convenient and practical reference for the colors most frequently encountered by vertebrate biologists, and its very brevity answers some of the criticisms of Ridgway's COLOR STANDARDS (1912). The authors subscribe more closely to Villalobos' ATLAS (1947) with its more than 7,200 color squares identified by coded symbols.

The center two-page spread offers chips of 48 different hues. These comprise a chromatic hexagon of 20 basic spectral groups (the reds, yellows, greens, blues and purples, with such intermediates as orange, ruby and cobalt); an "arbitrary" group of 21 named colors, *e.g.* the familiar fuscous, rufous, tawny and olive; and a neutral scale of seven tones from white through the grays to black. Names are provided for all 48 chips, equivalents are listed in the Ridgway and Villalobos nomenclature, and a system is suggested for indicating shades of difference, lightness or texture by modifying terms. Excluding only metallic and rarely-used terms, and certain bizarre ones, the system would seem adapted for representing the great majority of colors mentioned by biologists. It should prove a boon to those who wrestle with the problem of designating an elusive shade of color.—RICHARD H. MANVILLE.

Leyhausen, Paul. VERHALTENSSTUDIEN AN KATZEN. Supplement No. 2 to *Zeitschrift für Tierpsychologie*. Verlag Paul Parey, Berlin & Hamburg. 120 pp.; 76 figs. July 1956. Paper cover, DM 23,80.

This monograph on cat behavior is based on observations and experiments on thirty caged and numerous free-ranging domestic cats, as well as on other species in many German zoos. The printing is of high quality, on good paper. The illustrations—many halftones and some line drawings—are clear and informative. Subject, species, and author indexes are provided, as well as a four-page Summary in English.

Predation and social behavior are emphasized. The stalking methods of cats, the *coup de grâce* administered by a bite into the nape, and the plucking of feathers or fur before devouring, are described in detail. One learns that small animals are always eaten head first; that cats seldom masticate their food; that domestic cats are specialized for capturing smaller animals than rats, and their ability to kill these rodents depends on their individual "cour-

age," related in turn to social rank. Being solitary animals by nature, cats do not develop rigid social orders, although under crowded conditions one may assume temporary dominance. In the wild they do defend their fairly large hunting territories, at least in part, as well as their home areas, against intruding cats. Threatening and defensive behavior are described, as well as play, courtship, mating and parental care. Comparisons are drawn to the Viverridae, Mustelidae and some other primitive mammals. It is interesting to note that taxonomic differences between the *Felinae* and *Pantherinae* are reflected also in their feeding habits and mating behavior.—RICHARD H. MANVILLE.

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COMMENTS AND NEWS

THIRTY-SEVENTH ANNUAL MEETING

The thirty-seventh annual meeting of the American Society of Mammalogists will be held in the Memorial Union Building, University of Kansas, Lawrence, Kansas, on June 18–20, 1957. The Directors' Meeting will be at 8:00 P.M., on June 17. Open sessions will begin on the morning of June 18. A call for papers will be distributed to all members by the Corresponding Secretary in the spring; the deadline for submitting titles of papers for presentation will be May 1. The Chairman of the Local Committee will be E. Raymond Hall.

Recommended housing is the newly constructed, air-conditioned Gertrude Sellards Pearson Hall, 11th and Louisiana Sts., having ample parking space, 4 blocks from the Union Building. Rooms have twin beds and rates are $2.50 per person when two persons share a room. The rate is $4.00 for one person in a room. Children, $1.00 extra per child. Make reservations in advance by writing to "Institutes and Conferences, Blake Annex, University of Kansas, Lawrence, Kansas, attention Mr. Richard Taylor." No deposit is required.

Meals will be available in the Union Building.

Tent sites (shade and water), and shelter for those having sleeping bags, are available at the old farmstead on the University Experimental Area 7 miles northeast of the University.

Motels and Hotels (Post Office address, Lawrence, Kansas), within 2½ miles of the Union Building, include the following:

Town Manor, 601 Louisiana St.	Westview Motel, 1313 West 6th St.
College Motel, 1703 West 6th St.	Airport Inn, RFD No. 4
Virginia Inn, RFD No. 1	Jayhawk Court, RFD No. 3
Holiday Inn, 23rd and Iowa Sts.	El Navajo Court, RFD No. 1
Eldridge Hotel, 7th and Massachusetts	Lawrence Motel, 624 N. 2nd St.

Rates for air-conditioned rooms range from $3.50–$7.00 for a single person to $4.50–$9.00 for two persons. The listing above is roughly from most expensive to least expensive. For reservations, write directly to the hotel or motel of your choice.

Lawrence, Kansas, is served by the Santa Fe, Union Pacific, and Rock Island railroads and Greyhound and Trailways bus lines.

In Lawrence, taxi service and busses at 20-minute intervals are available between the downtown area and the Memorial Union Building on the University Campus.

Persons arriving at Kansas City by air will find transportation to Lawrence (45 min. to 1 hr. 20 min.) as follows: A.M. 12:30 Trls.; 1:00 Gr.; 5:00 Gr.; 6:30 Trls.; 7:30 Trls.; 8:30 S.F.; 8:45 Gr.; 9:15 U.P.; 10:00 Gr. P.M. 12.05 Gr.; 12:30 Gr.; 1:30 Gr.; 2:35 Trls.; 3:30 Gr.; 3:40 Trls.; 5:00 Gr.; 5:30 S.F.; 6:00 Gr.; 6:15 Gr.; 9:30 S.F.; 9:40 Gr.; 11:00 U.P.; 11:45 Gr.

Explanation of abbreviations: Gr.–Greyhound Bus. S.F.–Santa Fe Railroad. Trls.–Trailways Bus. U.P.–Union Pacific Railroad. All trains leave Kansas City Union Station. Greyhound Bus Station at 917 McGee Street, Kansas City, Mo.; Trailways Bus Station is one and one-half blocks away at 11th and McGee Streets.

PICTURES WANTED

The Society desires to complete its collection of group pictures taken on the occasion of its annual meetings. The official files at present contain pictures from the following years: 1919, 1926, 1932, 1938, 1940–42, 1944, 1947–48, 1950–56. The Corresponding Secretary would welcome word from anyone willing to donate pictures from other years. It would be most helpful if identification of as many individuals as possible were also provided.

PROPOSED AMENDMENTS OF BYLAWS

Article III Officers

SEC. 1.

From: The officers of the Society shall be a President, two Vice Presidents, a Recording Secretary, a Corresponding Secretary, and a Treasurer. These, together with the Editor, the Ex-Presidents, and ten persons elected from the Society at large, shall constitute the Board of Directors of the Society.

To: Elective officers of the Society shall be a President, two Vice Presidents, and a Recording Secretary. These, together with the Secretary-Treasurer, the Editor, the Ex-Presidents, and ten persons elected from the Society at large, shall constitute the Board of Directors of the Society.

SEC. 2. Amend second sentence

From: The Editor shall be appointed by the Directors.

To: The Secretary-Treasurer and the Editor shall be appointed by the Directors, provided, however, that a petition signed by 20 per cent or more of the members in good standing at any annual stated meeting will be sufficient to require the Board of Directors to submit a ballot to the members present at said meeting to determine their approval or disapproval of either incumbent.

SEC. 4. (New).

The Secretary-Treasurer shall be the Executive Officer of the Society under the general direction and subject to regulations of the Board of Directors. He shall be bonded at the Society's expense in the amount specified by the Board of Directors. He shall conduct the business affairs of the Society, issue notices of annual or special meetings, and present a monthly financial report to the President and an annual report of his activities to the Society at the annual stated meeting. He shall, subject to regulations of the Board of Directors, be responsible for all funds of the Society, except for the permanent funds which shall be under the supervision of the Board of Trustees. The general fund accounts shall be subject to the signature of the Secretary-Treasurer.

Article IV Meetings

SEC. 1. Amend last sentence

From: Due notice of such meetings shall be given by the Corresponding Secretary.

To: Due notice of such meetings shall be given by the Secretary-Treasurer.

Article VIII Fees and Accounts

SEC. 3. Amend last sentence

From: The accounts of the Treasurer shall be audited, as directed by the President, at the close of each year before presentation at the annual stated meeting of the Society.

To: The accounts of the Secretary-Treasurer shall be audited, as directed by the President, at the close of each year before presentation at the annual stated meeting of the Society.

PUBLICATIONS AVAILABLE

A revised list of sales publications has been compiled by the New York State Museum and is available on request to the Museum at Albany 1, New York. This list includes a number of zoological bulletins, circulars and handbooks that were formerly considered out of print and have been available only through dealers. The stock of some of these items is small; in such cases, preference will be given to orders from libraries of universities, foundations and other organizations.

ZOOLOGICAL NOMENCLATURE

Notice of proposed use of the Plenary Powers in certain cases for the avoidance of confusion and the validation of current nomenclatorial practice (*A.* [*n.s.*] *30*).

Notice is hereby given that the possible use by the International Commission on Zoological Nomenclature of its Plenary Powers is involved in applications relating to the undermentioned names included in Part 6 and Double-Part 7/8 of Volume 12 of the *Bulletin of Zoological Nomenclature*, both of which Parts will be published on 24th August 1956:

(1) *Applications in Double-Part 7/8 of Volume 12 [Only two on Mammalia].*

Elaphella Bezzi, 1913, and *Lophiotherium* Gervais, 1850, validation of (Class Mammalia) (Z.N. (S.) 1077).

(2) The present Notice is given in pursuance of decisions taken, on the recommendation of the International Commission on Zoological Nomenclature, by the Thirteenth International Congress of Zoology, Paris, July, 1948 (see *Bull. Zool. Nomencl.* 4:51–56, 57–59; *ibid.* 5:5–13, 131).

(3) Any specialist who may desire to comment on any of the foregoing applications is invited to do so in writing to the Secretary to the International Commission (Address: 28 Park Village East, Regent's Park, London, N.W.1., England) as soon as possible. Every such comment should be clearly marked with the Commission's File Number as given in the present Notice.

(4) If received in sufficient time before the commencement by the International Commission of voting on the applications in question, comments received in response to the present Notice will be published in the *Bulletin of Zoological Nomenclature;* comments received too late to be so published will be brought to the attention of the International Commission at the time of the commencement of voting on the application in question.

(5) Under the decision by the International Congress of Zoology specified in paragraph (2) above, the period within which comments on the applications covered by the present Notice are receivable is a period of six calendar months calculated from the date of publication of the relevant Part of the *Bulletin of Zoological Nomenclature.* The Parts now in question will be published on 24th August, 1956. In consequence, any comments on the applications published in this Part should reach the Secretariat of the International Commission at the latest by 24th February, 1957.—Francis Hemming, *Secretary to the International Commission on Zoological Nomenclature.*

EXCHANGES WITH SOVIET MAMMALOGISTS

The following announcement has been received from E. N. Pavlovsky, Director of the Zoological Institute of the Academy of Sciences of the U. S. S. R., Leningrad: "Our Institute deals with the studying of systematics, fauna, ecology, biocenology, and parasitology of the wild animals of our country.

"The connection of the Zoological Institute . . . with the American Society of Mammalogists is very desirable by means of the exchange of scientific literature, museum materials, and personal examination of Zoo museums and Zoological Gardens . . . . What mammalian species are you interested in for exchange and what can you offer in return?"

E. W. Pfeiffer has offered to serve as intermediary and anyone interested may contact him at the Department of Zoology, Utah State Agricultural College, Logan.

NEW ECOLOGICAL SECTION

The Ecological Society of America announces the formal organization of a Section of Animal Behavior and Sociobiology. Its purpose is to advance, coordinate and assist research and publications on the subject of animal behavior and social organization basic to theoretical science and human welfare, and to act as a liaison agency between workers in the various fields concerned. Officers elected are J. P. Scott, Chairman; A. M. Guhl, Vice-Chairman; and M. W. Schein, Secretary. It is planned to continue the programs of research papers held for several years and to issue a mimeographed Newsletter. Potential members of the Section represent a wide variety of interests, covering every form of animal life as well as the more generalized biological fields. Anyone interested is invited to join. Members of any class of the Ecological Society of America may affiliate by simply writing to the Secretary of the Section, Dept. of Poultry Husbandry, Pennsylvania State University, University Park, Pa.

NEW JOURNAL

A new journal entitled C.S.I.R.O. WILDLIFE RESEARCH is announced by the Commonwealth Scientific and Industrial Research Organization. It will be devoted mainly to the results of field research by the Wildlife Survey Section of the C.S.I.R.O. on the ecology and economics of the native and introduced fauna of Australia. Studies of mammals and birds, ranging in scope from fundamental population, behaviour, and physiological aspects to practical control methods, constitute most of the Section's work. The journal will contain papers on research results and techniques, occasional reviews, and short contributions. Vol. 1, No. 1 appeared in September, 1956; two issues per year are planned, priced at 10/– each. Subscriptions may be placed with The Secretary (General Administration), C.S.I.R.O., 314 Albert Street, East Melbourne, C.2, Victoria, Australia.

DEATH REPORTED

John W. Scott, August 15, 1956

DATE OF ISSUE OF PREVIOUS NUMBER

Journal of Mammalogy, Vol. 37, No. 4, was mailed January 9, 1957